LLUMINATING ENGINEER

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THE ILLUMINATING ENGINEER

LIGHT LAMPS FITTINGS AND ILLUMINATION

THE JOURNAL OF GOOD LIGHTING

OIL . GAS ELECTRICITY ACETYLENE PETROL-AIR GAS ETC.

OFFICIAL JOURNAL of
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(Founded in London, 1909, Incorporated 1930)
and of
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J. STEWART DOW

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Luminous Discharge Tube Lighting

THE address on the above subject given before the Illuminating Engineering Society by Mr. C. C. Paterson, on November 8th, marked the commencement of what may well prove to be a new era in electric lighting. Luminescent vapours and gases seem destined to play a much more important rôle than in the past. Already the rapid development of neon-tube lighting has furnished a valuable supplement to lighting by means of incandescent filaments. A visitor to Piccadilly Circus, after some years' absence abroad, could not fail to be struck by the extension of this system of lighting, as well as the variety, both in colour and design. In particular, the introduction of "animated" effects (until recently regarded as feasible with incandescent lamps only) would excite remark.

But all these manifestations of gaseous discharge tube lighting are, as Mr. Paterson remarked, characterized by features which limit their applications—such as the colour, the necessity for using a high voltage, and the relatively low luminosity of the tube. The latter, whilst an advantage when light is used as an element in decoration, is an evident drawback when the light is intended to illuminate other objects, and scientific direction becomes of importance. In these circumstances some degree of concentration of light is desirable. It is also expedient that the lamp should operate on ordinary supply voltages.

These two conditions have already been met, with a very fair measure of success, in the new hot-cathode lamps. The new form of lamp developed in the G.E.C. Research Laboratories at Wembley can be operated on an ordinary supply voltage, consumes 400 watts and furnishes about 40 lumens per watt (as compared with 15 lumens per watt from the gasfilled tungsten-filament lamp). This substantial volume of light is emitted by a column of vapour only about 6 ins. long. East Lane, adjacent to the laboratories, was lighted by such lamps on the occasion of the visit (the lamps had previously been lighted for the first time in June last). The street appeared brightly illuminated, the colour (a species of greenish-white) was not unpleasing, and the vertical luminous column furnished a distribution of light well adapted to street lighting.

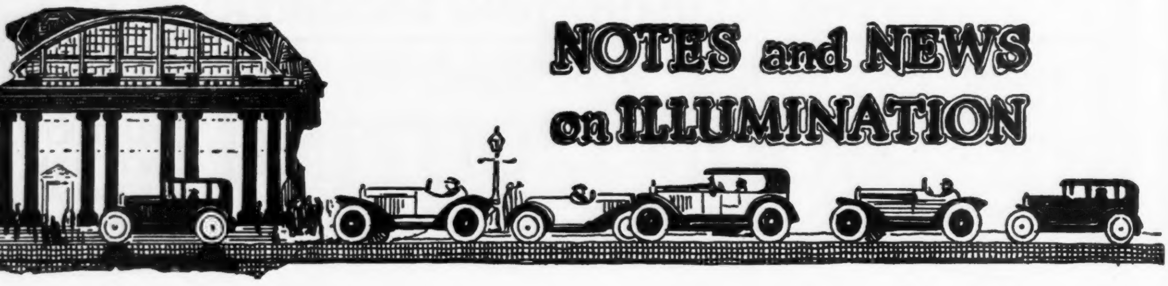
Reference was made to another form of discharge tube lamp, utilizing sodium vapour, of which examples were also seen. In this case a higher efficiency, 70 lumens per watt, is stated to be attainable with the lamps intended for street lighting. The unusual orange light yielded from these lamps is, however, something of a drawback. Combinations of hot-cathode tubes (i.e., those using neon and mercury) have interesting possibilities.

These efficiencies, it may be noted, are still much below the maximum theoretically obtainable—670 lumens per watt for monochromatic light in the greenish-yellow region of the spectrum, where the sensitiveness of the eye is at its greatest. But a strictly monochromatic light such as this, whilst difficult to produce, would also have limited applications, and its efficiency would inevitably be diminished by various unavoidable losses within the tube. Nevertheless, one is encouraged to think that the limits of research are very far from having been reached, and that further substantial advances may be expected before very long.

The gain in efficiency now recorded is naturally of great importance, but even more significant, perhaps, is the evidence of gain in control over the *quality* of radiation. In the case of incandescent solids, which emit a jumble of forced vibrations—mainly of a non-luminous character—our control is very imperfect, and the "white" light is obtained only by a great sacrifice in efficiency. In the case of luminous gases the proportion of energy radiated in a luminous form is much greater and the quality of radiation is more restricted. We have now at our command a wide range of colours. The time is approaching when we may no longer need to produce coloured light by the costly and inefficient use of filters. We are, however, still far from the ideal aim of being able to produce at will just those wavelengths we desire, and those only.

We would like to conclude this note by an expression of thanks, which all those who visited Wembley on November 8th would desire to see recorded, not only to Mr. Paterson for his fascinating address, but to his staff for the great amount of trouble they took to render the visit interesting and agreeable, and to the General Electric Company for their very generous hospitality.

Members of the Illuminating Engineering Society showed their recognition of the importance of the occasion by assembling from all parts of the country and bringing numerous contingents of friends. In these days of industrial depression, too, it is pleasant to encounter records of research carried out with such perseverance and presented in such an enterprising way.



The Building Centre

The visit of members of the Illuminating Engineering Society to the Building Centre Ltd. (158, New Bond Street, London), on November 22nd, proved to be a popular event. Everyone was interested in the variety of equipment on view. To the general regret, Mr. H. T. Young, who had intended to be present to receive the visitors, was prevented by indisposition from doing so. Mr. A. B. Read and Mr. John Hall, however, kindly attended in his stead, and Mr. V. W. Dale and others from the E.D.A. also assisted in showing the party round. It would be exceedingly difficult to attempt an adequate description of the exhibits, which illustrate applications both of gas and electricity, for heating and lighting and other purposes. One can only wonder how such an exhibit could have been got together within a few months. The three floors available have been most economically utilized. In a number of cases the actual use of objects (e.g., in bedrooms and bathrooms) is illustrated, though naturally only a small percentage of the total assembly of exhibits can be treated in this way. The planning of the centre has been done under the supervision of architects. The demonstration of how apparatus could best be installed was often as interesting as the thing itself. At the conclusion of the visit Mr. V. W. Dale said a few words explaining the origin of the display. In the absence of the President, who had been detained owing to inclement weather conditions, Mr. J. S. Dow moved a cordial vote of thanks to the Building Centre Ltd. and to Mr. Dale and the others who had kindly acted as guides.

We strongly advise any readers who have not yet visited the Building Centre (which is now open for general inspection) to do so.

(Particulars of forthcoming meetings of the Illuminating Engineering Society will be found on p. 307.)

Illuminating Engineering in Manchester

We hear that the members of the Illuminating Engineering Society in Manchester, for whom Mr. James Sellars is acting as hon. secretary, have already been taking part in several meetings and visits. On October 20th a visit to Blackpool, in order to see the illumination, was arranged under the direction of Mr. C. E. Furness, the Electrical Engineer. Opportunities have since been afforded to members to hear addresses by Mr. A. B. Read and Dr. J. W. T. Walsh on "The Electric Lighting of Buildings," and by Mr. C. C. Paterson on "Luminous-tube Lighting." Other meetings are in prospect, and a number of additions to the membership of the North-West Area have recently been made. We advise all those in the district who are interested in illumination, and who may be glad to know that a circle of members of the Illuminating Engineering Society is thus developing, to get in touch with Mr. James Sellars (Highways Department, Town Hall, Manchester).

Football by Floodlight

A short time ago there was much discussion regarding the expediency of playing Association football matches on floodlighted grounds as evening spectacles. For various reasons the idea came to naught. It now seems that a similar fate has overtaken the proposed "floodlit" Rugby match at the White City. Apparently the "powers that be" are not yet favourably disposed to the idea of playing football matches by artificial light. Governing bodies are apt to be conservative in such matters. Doubtless commercial considerations, as well as technical difficulties, play a part. To illuminate an area in such a manner as to enable football (by either code) to be played with at least the same ease as by average winter daylight may not seem a very difficult feat. It has, in fact, been attempted already with very fair success, both in this country and abroad. The experimental demonstration at the Arsenal Football Ground, on November 28th, whilst indicating that perfection has not yet been achieved, seemed encouraging. Players apparently found no difficulty in following the flight of the ball, and the play could be seen with ease in spite of the misty and unfavourable weather conditions. Doubtless, however, greater difficulty would have been experienced at the vast distances found in a full-sized football arena. The advantage of utilizing artificial light during the winter, when the period of natural light is so limited, is evident. Comparatively few people are at liberty either to play or to watch any game in winter during daylight hours. Exhibition games are often handicapped by failing daylight. The Oxford v. Cambridge Rugby match (on a date so strangely selected as almost to coincide with mid-winter) is notoriously apt to terminate under conditions when neither players nor spectators can see much. It ought surely to be feasible at least to help out deficiencies in natural lighting by artificial means.

Hotel Lighting

The E.D.A.-E.L.M.A. hotel-lighting campaign, now well under way, is being aided by some attractive literature, notably the two illustrated booklets, "Bring Lights" and "Light in the Hotel." This is a field where there is obvious room for improvement. We must confess that we have a special objection to "Ye Goode Olde . . ." hotel, which sometimes sends us to bed by candle, but more frequently consents to the introduction of electric light and then misuses it. There are doubtless opportunities for floodlighting, decorative effects and lighted canopies. We hope, however, that efforts will be directed mainly to correcting elementary mistakes in method, rather than inducing a blaze of light. It is surely more important that guests should be able to read in bed with ease, to write their letters in comfort, and to eat their food in the midst of lighting which is pleasant and restful than that they should be greeted by dazzling constellations and elaborate multi-coloured decorative effects.

Luminous Discharge Tube Lighting

(Proceedings at the Meeting of the Illuminating Engineering Society, held at the Research Laboratories of the General Electric Company, Wembley, at 6-30 p.m., on Tuesday, November 8th, 1932.)

A MEETING of the Illuminating Engineering Society was held at the G.E.C. Research Laboratories, Wembley, on Tuesday, November 8th. Members and friends assembled for light refreshments at 6-30 p.m., when Lieut.-Commander HAYDN T. HARRISON, M.I.E.E., R.N.V.R. (President), took the chair.

After the minutes of the last meeting had been taken as read, the HON. SECRETARY read out the names of applicants for membership, which were as follows:—

Sustaining Member:—

The Newcastle-upon-Tyne and Gateshead Gas Company, 33, Grainger Street West, Newcastle-upon-Tyne. *Representative*: Mr. J. R. Hepple.

Corporate Members:—

Balbi, C. M. R. ....Electrical Engineer, 4, Iddesleigh House, Caxton Street, Westminster. London, S.W.1.

Franklin, G. ....Designer, Messrs. Ingram & Kemp Ltd., 92, Westminster Road, Birchfields, Birmingham.

New, Valentine G. ....Manager, The Street Lighting Improvement Co., 14, Victoria Street, London, S.W.1.

Stevens, A. H. ....Lighting Assistant, L.M.S. Railway; 29, Middle Way, Hampstead Garden Suburb, London, N.W.11.

Stoyle, W. A. R. ......Electrical Engineer, 117, Carlton Avenue East, Wembley, Middlesex.

Country Member:—

Kay, Rupert ....Commercial Traveller (Engineering), 1, Cross Road, Chorlton-cum-Hardy, Manchester.

The names of those announced at the last meeting of the Society were read again, and these gentlemen were formally declared members of the Society.*

The PRESIDENT then called upon Mr. CLIFFORD C. PATERSON to deliver his address on "Luminous Discharge Tube Lighting." The lecture, which was illustrated by numerous lantern slides, was followed with close attention. In the introduction the author recalled the beginnings of electric incandescent lamps in order to illustrate the difficulty of predicting the ultimate possibilities of the luminous discharge tube lighting. In a subsequent section of the address Mr. Paterson raised the query: "Why does a tube radiate light?" and discussed the underlying physical phenomena. The nature of the familiar cold-cathode lamps and their spectra was next explained, after which the main section of the lecture—the account of the new hot-cathode discharge tubes—was entered upon. In conclusion, the author referred to some special characteristics of the new lamps, such as their high efficiency (up to 70 lumens per watt), the variation in colour of light occasioned by altering the contents of the tube, the problems involved in their photometry, and the "successive image effect."

The PRESIDENT, at the conclusion of the lecture, moved a cordial vote of thanks to Mr. Paterson for his informative address, to his staff for arranging such a delightful visit, and to the General Electric Co. Ltd. for their generous hospitality. After this had been carried with acclamation, and the Hon. Secretary had announced forthcoming meetings, visitors were conducted in parties over the laboratories, where many interesting things were seen. Naturally, visitors were specially attracted by the display of luminous tubes, both of the cold- and hot-cathode types. Amongst the former were tubes containing neon, mercury and helium, and there was a specially entertaining exhibit consisting of tubes giving varied forms of "flicker-wave" effects. The hot-cathode tube lamps shown in the laboratory included some based on the use of sodium and giving a vivid orange light, and others of the newly-evolved G.E.C. Wembley pattern giving light of a greenish-white hue. A series of 400-watt lamps of the latter type, mounted in East Lane adjacent to the laboratory, formed a most imposing exhibit as one proceeded from the laboratories to North Wembley station; visitors also had a glimpse of the floodlighting with hot-cathode neon projectors of the adjacent glassworks.

Other items included demonstrations of the production of coiled tungsten filaments, radio reception and photo-electric cells. A specially interesting application of the latter was for the measurement of surfaces of irregular area, the diminution in light caused when such areas were placed on an evenly illuminated sheet of diffusing glass being observed.

There were also numerous instruments in the photometric laboratories, amongst which we may single out the now-familiar "Ray-Path" apparatus, a photometer for testing opal glasses, and the "model street." Photometers of varied types were seen. Apart from those used in the laboratory for routine testing and research, there were a number of portable types of novel design. One very compact form was adapted to observations of illumination on a test-plate in streets and open places (a feature being the illuminated scale on which values of illumination are read). Of special intreest also is the "telephotometer," which is useful for examining distant objects. The latter is evidently a very convenient apparatus for exploring the variation in brightness of the surfaces of floodlighted buildings, etc.

The attendance (over 200) was probably a record at a general meeting of the Society, many members having come up to town specially for the event, and everyone agreed that the evening had been a most agreeable and instructive one.

* *Illum. Eng.*, November, 1932, p. 275.

The Illuminating Engineering Society

FORTHCOMING MEETINGS.

Members are reminded that the **Next Meeting** of the Society, which will take place at the Caxton Hall, Westminster, S.W.1, at 6-30 p.m., on **Tuesday, December 13th,** will be a joint gathering with the Society of Glass Technology. An introductory address reviewing the work of the B.S.I. Committees dealing with **Diffusing (Opal) Glassware** will be delivered by Dr. S. ENGLISH. Other contributions will include a discussion of the Theory of and Specification of Opal Diffusing Glassware, which will be treated respectively by Mr. J. W. Ryde and Mr. B. S. Cooper (Part I) and by Mr. B. S. Cooper and Mr. W. A. R. Stoyle (Part II), and a paper dealing with The Manufacture of Opal Glassware will be read by Dr. W. M. Hampton.

On **January 10th** members will be the guests of the Gas Light and Coke Company at **Watson House,** and will have an opportunity of seeing over the laboratories and workshops.

The **Annual Dinner** will be held at the Trocadero Restaurant, Piccadilly, London, W., on **February 7th** (7 for 7-30 p.m.), when it is hoped that all members will make a special effort to attend.

Luminous Discharge Tube Lighting

By CLIFFORD C. PATERSON, O.B.E., M.Inst.C.E., M.I.E.E.

(Lecture delivered at the Meeting of the Illuminating Engineering Society, held at the G.E.C. Research Laboratories, Wembley, at 6-30 p.m., on Tuesday, November 8th, 1932.)

Introduction.

We feel very confident that the luminous discharge tube is to play a big rôle in electric lighting of the future. One bases this opinion more upon a broader survey of the physics of the subject than upon what has already been achieved in decorative and display lighting, noteworthy as this undoubtedly is. Whilst one cannot at present point with any certainty to a given combination of the many and complicated phenomena which are embraced by the term luminous discharge, and predict that this or that will be the line of big industrial advances—one can, without hesitation, say that the limits to progress set by theoretical considerations are, in the case of the discharge tube, far wider than physical laws permit in the case of the incandescent filament lamp. Perhaps this is particularly so when we consider efficiency. A light efficiency of many times

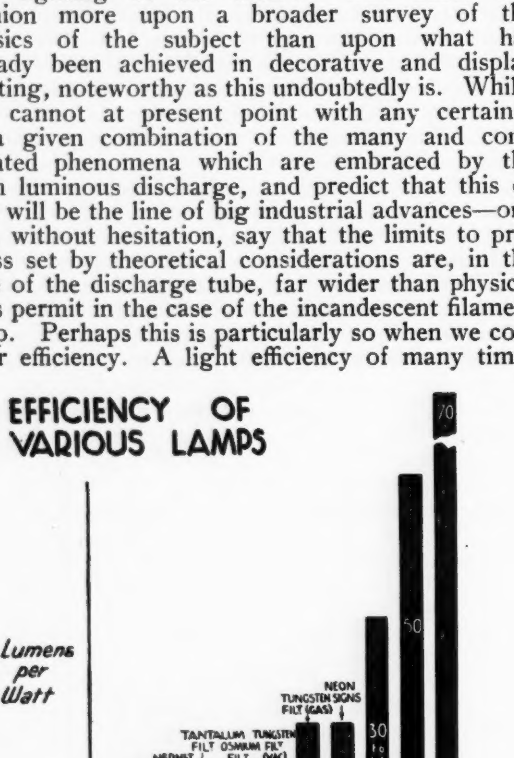


Fig. 1.

that of the filament lamp is already certain. In colour the discharge lamp has a wide flexibility, although we cannot yet always achieve exactly what we want in reproducing the conditions which daylight imposes upon us. In geometrical form we shall have a much wider choice than the filament lamp can ever give. On the score of electrical simplicity nature has not been so kind to the gas-discharge lamp. It is probably here that the filament lamp will ultimately have its chief bargaining point. But even here we must not lose our perspective. When in 1878 Swan first produced his electric lamp with its carbon filament about $\frac{1}{32}$ in. diameter and 1 in. long, if as much had been known about gas-discharge tubes as we know to-day, what would have been the views of the experts on the question of which system would yield the most commercial 230-volt lamp? Would anyone have believed that a filament of the size of the thread of a spider's web could have been made to glow for 1,000 hours at a temperature of 2,700° with no more than 1 per cent. of failures before 500 hours? Would not everyone have pointed to the gas-discharge lamp as the only promising avenue for electric lighting? It is true that the discharge lamp is to-day further advanced than the filament lamp was in Swan's day, but one must admit that to-day there is probably as much to find out in the theory and possibilities of the gas-discharge lamp as in 1878 there was to discover in the filament lamp.

This is not predicting the early or even the ultimate substitution on a large scale of the present filament lamp by discharge lamps. The filament lamp is too simple and effective a product of engineering and scientific skill to be thus displaced. But the discharge lamp is certainly going to evolve its own field of usefulness and weave itself into our picture of electric lighting of the future.

The object of this lecture is to explain those features and characteristics of discharge lamps which the engineer needs to grasp if he is to have the same intelligent appreciation of the way they function as he now has in the case of the filament lamp. No one who speaks to electrical engineers these days needs to apologize for assuming a general knowledge of atomic physics. That has become as much a part of our intellectual stock-in-trade as Ohm's law was to the engineer of 20 years ago. Let us bear in mind, however, that there are still many engineers with us who learnt their engineering in Ohm's law days. Will any latter-day engineers therefore overlook what will sometimes be an assumption in what follows of too little knowledge of the atom and its manner of emitting electromagnetic radiation?

Why Does a Tube Radiate Light?

We had better be clear, first of all, about what is meant by a gas-discharge tube. For present purposes is meant a tube with transparent walls in which are two electrodes, one at each end, across which the voltage is applied. The gas in the tube is carefully controlled as to quantity and purity, so that it radiates light as we want it to, under the influence of the current which passes through it from one electrode to the other.

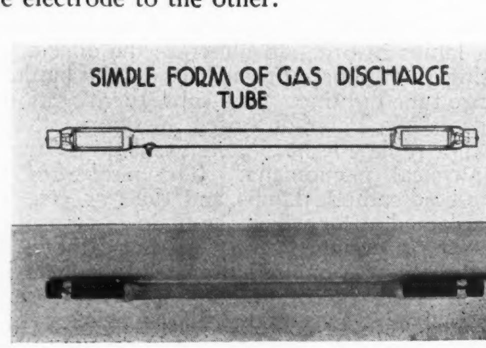


Fig. 2.

In Fig. 2 is such a tube. It is an example of the type used extensively for advertising signs. The first thing, of course, to notice is that, unlike an incandescent lamp, it has nothing visible connecting the two electrodes inside the tube. How, then, is current to pass and light to be radiated? The superficial answer is that the tube is filled with a gas at low pressure; it is this which both conducts the current and gives off the light. But it is vital to our intelligent understanding of the subject of discharge tubes that we should have a picture in our minds of the manner in which the gas does this. It will not, however, be possible to do more than give a very brief outline of this fascinating but most complicated process.

Except in extra high-tension work, we are accustomed to think of the air as an insulator. Imagine the difficulties which we should encounter if it were even a moderate conductor at ordinary supply voltages! Refined measurements do, however, show that the air and other gases are not perfect insulators. An extraordinarily minute current does indeed flow between two electrodes in air, even when the voltage is quite low. This current is, however, so small that it would need to be enormously magnified before it would be measurable on a sensitive galvanometer. Although utterly negligible in most work, it must not be thought to be unimportant. As a matter of fact, it was owing to the careful study of this minute conductivity of the air that the penetrating radiation from outer space, now known as the cosmic rays, was discovered.

We have good reason to believe that if a gas could be completely shielded from this and other radiation or sources of ions, it would be strictly a perfect insulator. Actually, however, these cosmic rays and other ionizing agents produce about 100 ions per second in the 400 million million million molecules of gas present in every cubic inch of the air around us, and also, of course, of the gas in our tube. If a small potential difference is applied to the electrodes these primary ions travel through the gas and constitute a very minute current. When the voltage is increased a time comes when some of the ions, in colliding with the gas atoms, will produce other ions, and these again still more. The number of ions thus rapidly increases at compound interest until the flow is so great that it constitutes an appreciable current. Our insulating gas has thus in effect become highly conducting. It is of interest, however, to realize that without these primary ions in the gas to start with, it would refuse to react to the voltages we apply to our tubes, and there would be nothing to start up the complicated train of phenomena we are about to consider. We must not, however, suppose that the gas will behave as an ordinary metal conductor would do. We shall find that it does not obey Ohm's law, and that it also behaves in other peculiar ways, some of which we shall touch on later. Before leaving the question of how the discharge starts and the gas becomes conducting, there is one further point to be cleared up. Why must the gas be at a low pressure?

If the gas in our tube were at atmospheric pressure, we should have to apply a potential of many hundred thousand volts before the discharge would start, and when it did, it would take the unwanted form of a spark. As we decrease the gas pressure we find that the necessary starting voltage becomes considerably reduced. This is because the gas atoms are farther apart and the primary ions can thus gather more speed before collisions. At very low pressures, however, you will see that the voltage needed will rise again, since there are then comparatively few atoms present, so that the chance of ionization becomes very small. The starting voltage of our gas-discharge tube will thus be a minimum at a certain pressure which, in the case of neon gas, is of the order of a few millimetres of mercury. One other important point is that the visible form of the discharge changes as the pressure is reduced, and instead of a spark we find that the tube becomes filled with a luminous glow.

Now for the second question. How is this light produced? A wire through which a current is passing does not emit light unless it is being heated by the current to a high temperature. Then the light emitted is just the same as if the wire had been heated to the same temperature by a flame instead of by a current. When analysed by a spectroscope the radiation will be found to be "continuous," that is, a certain amount of each wavelength will be found in it. The radiation from a luminous discharge in a gas or vapour is, in general, quite different from this. On analysis, only certain wavelengths, all hightly characteristic of the gas, are found to be present.

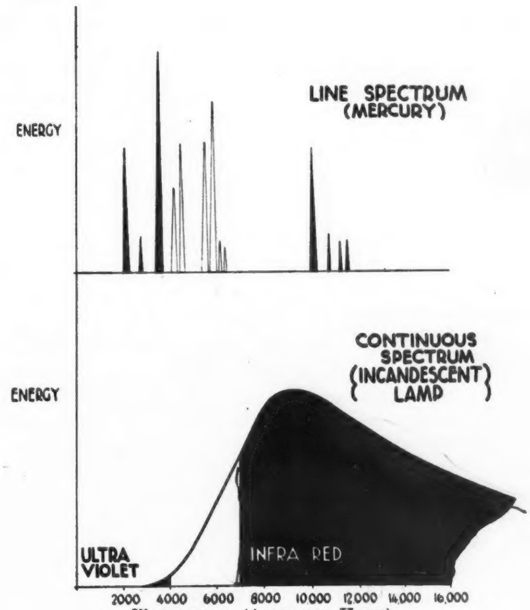


FIG. 3.—Energy Distribution in Continuous and Line Spectia. (Not to same scale.)

A normal atom of a gas consists of a central positively charged nucleus round which negatively charged electrons revolve in certain orbits. Now suppose an electron or ion to be moving under the influence of the voltage gradient along our tube. We have seen that, as it moves, it is continually colliding with the gas atoms; actually a collision will take place about every tenth of a millimetre of its path when the gas is at the low pressure we are considering. So long as the velocity is small, which the ion has gathered in its fall through the voltage gradient along its track, it will rebound at each collision just as if the atom and ion were perfectly elastic billiard balls; their combined energy of motion will be the same after as before the collision. But as the voltage between the ends of the tube is increased the velocity, and therefore the energy which the ion acquires in its fall, will also increase, and when this becomes greater than a certain critical value an extraordinary thing happens. The whole of this critical amount of energy is used up in transferring one of the electrons revolving round the atom to an exterior orbit not normally occupied by an electron. Any excess of energy over the critical amount needed for this, shows itself as kinetic energy of motion divided between the two bodies. The atom with its electron in an outer orbit is said to be

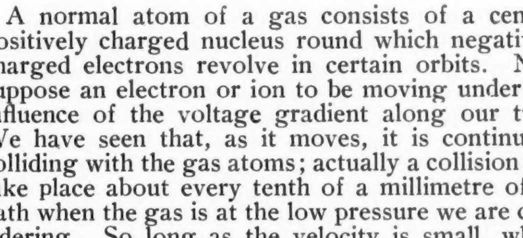


FIG. 4.

in an excited state. However, it generally does not long remain in this abnormal condition; the outer electron soon returns to its normal orbit, and in doing this the important thing happens. The energy which was absorbed in changing the orbit is now ejected as radiation. The additive effect of thousands of millions of atoms all behaving in similar ways gives us the radiation we observe from the tube. Radiation of what wavelength? The answer to this involves one of the most fundamental laws of modern physics. This remarkable relation, which to the physicist of to-day is what Ohm's law has been to the electrical engineer, states that the frequency of the radiation emitted is proportional to the energy emitted by the atom during the process of radiation.

Energy E = Planck's constant (h) × Radiation frequency (ν).

Since a short wavelength corresponds to a high frequency and vice versa, we see that the higher the energy of an atom in the excited state the shorter the wavelength of the radiation emitted when the electron returns to its normal orbit.

Now although we have only considered one critical energy value of excitation, all atoms have a vast number of such values corresponding to transitions of electrons to different orbits. Each kind of atom has its own characteristic set and, when recovering from the excitation by ionic collisions, emits radiations having a corresponding set of wavelengths.

If the energy of the colliding ion is gradually increased, a point will be reached when it has so much energy that, instead of transferring an electron in the atom to an extreme outside orbit, it succeeds in completely expelling the electron. The collision then results in the formation of two new ions, the atom, now positively charged (since it has lost an electron), and the free negatively charged electron which has been ejected from it. When this happens the atom is said to have been ionized. If this ionization has taken place in an electric field, these new ions dart down the voltage gradient and proceed to generate others, and these again still more by compound interest, thus initiating the discharge in the manner already described.

Before leaving the theoretical aspects of the discharge processes let us illustrate them by an example. Suppose our tube to contain sodium vapour at a low pressure. The critical energies and corresponding wavelengths for sodium are given in this table. The energies are given in terms of the voltage difference through which an electron must fall in order to acquire the corresponding energy. This gives a convenient energy unit known as the electron-volt.

Critical energy in electron-volts	Corresponding approximate wavelengths	Type of radiation emitted
2·1	5,890 A.U.	Yellow (D.)
3·2	11,400 „	Infra red
3·6	8,190 „	Infra red
4·1	6,160 „	Red
4·3	5,685 „	Green
.	.	.
.	.	.
.	.	.
5·12	Ionization	

If electrons are flowing through the vapour in circumstances such that they can never acquire an energy of more than 2.1 electron-volts (the first critical energy value) no light is emitted. But if we apply a potential sufficient to start a discharge through the vapour in our tube, the sodium ions so produced will have energies varying over a large range which must extend to a value at least as great as the ionization potential, 5.12 electron-volts. In consequence all the lines shown in the table and many other invisible ones will be emitted.

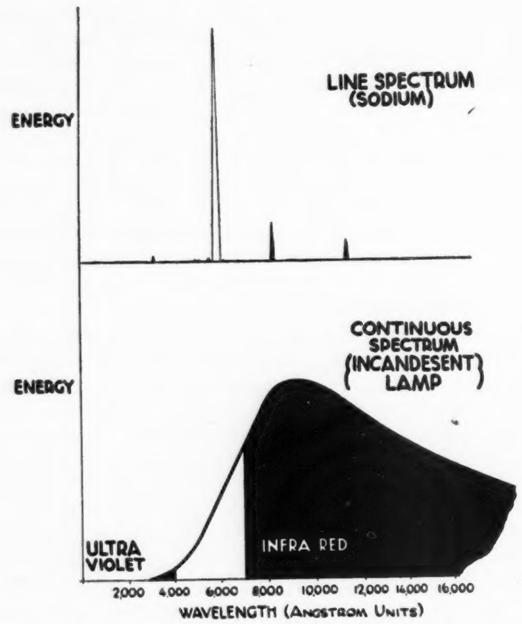


FIG. 5.—Energy Distribution in Continuous and Line Spectra. (Not to same scale.)

The various lines will not all be of the same intensity; in fact, with sodium, all the visible radiations other than the D lines at 5,890 are very weak indeed. For example, the green lines at 5,685 have an intensity of only about 1 per cent. of the yellow D lines.

We cannot enter here into the theory of the intensities of the lines. This is rather abstruse, but there is one important point to remember and to which we shall have occasion to return later—the fact that the relative intensity of the various spectrum lines changes with both the current and the pressure of gas in the tube.

We must have very clearly in our minds that the discharge between the electrodes is not uniform. It consists essentially of two parts—that immediately surrounding the metal electrodes, and that which constitutes the main column between them. It is the latter which gives most of the light, and it is the part we want for luminous tubes. However, the complication of the other part of the discharge—that immediately surrounding the electrodes—cannot be avoided. This contributes more than any other factor to the difficulties of the manufacturer and designer, and governs as a rule the life of the tube.

Its better understanding and control has been responsible, more than anything else, for improvements which have taken place during the past five or six years.

COLD CATHODE TUBES.

First let us consider the high-tension tubes, so widely used now for advertising and display. We will call these cold cathode tubes to distinguish them from others to be considered later.

If we trace the potential fall between the electrodes of one of these tubes when the current is passing, we find a sharp drop of voltage (known as the cathode fall) near the negative electrode, and then a uniform drop over the main luminous (or positive) column. The designer of a tube, therefore, needs to know both the value of the cathode fall and the voltage drop per unit length of the positive column. The sum of these will give him the

voltage required to run the tube after it is once started.

The voltage drop along the positive column is not analagous to that along a wire carrying current inversely as the square of the diameter. Furthermore, Ohm's law is not obeyed and we find that the volt drop decreases as the current increases. It also varies in a complicated manner with the pressure of the gas inside it. Briefly, it is found that as the

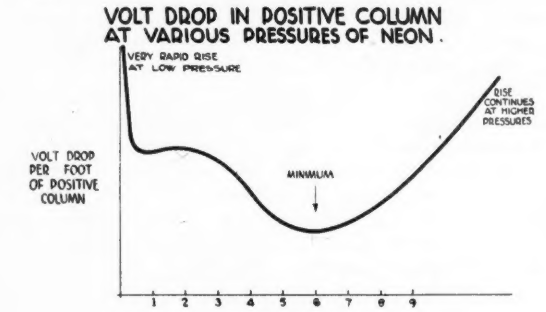


FIG. 6.

pressure is slowly decreased from a high value, the voltage drop decreases to a minimum value and then rises again; extremely rapidly at low pressures. In a 15 mm. diameter tube of the type we are considering, this minimum, with neon, occurs at about 6 mm. pressure and the very rapid rise takes place when the pressure has fallen below 1 mm.

The amount of the cathode fall depends upon various factors. When the current is such that the electrodes are just not completely covered with " glow " the cathode fall is called " normal." This normal cathode fall depends both on the gas used and on the material of which the electrode is made. Thus in neon gas the cathode fall is roughly 150 volts with iron electrodes, 140 volts with aluminium, and 120 with magnesium electrodes. On the other hand, with iron electrodes used with different gases, we find that the fall is 160 volts in helium, 150 in neon, 180 in argon, 270 in nitrogen, and nearly 300 in hydrogen. The normal cathode fall remains practically constant as the current is increased, until a time comes when the glow covers the whole cathode. If, after this, the current is raised any higher the fall is said to be in the abnormal state and may rise to several hundred volts. Tubes are generally designed to run at, or only slightly above, the normal cathode fall.

Given therefore a table of the volt drop per foot run, such as this—which is for pure neon gas—

R.M.S. volts per foot for a diameter of tube of 15 mm.—Neon

Current	6 mm. pressure	12 mm. pressure
ma.		
25	147	159
35	134	144
45	126	135

and a knowledge of the cathode fall, we may calculate the volt drop over the tube. Thus, take iron electrodes with 180 volts cathode fall used in a 10 ft. long tube running at 35 milliamps with a pressure of 6 mm. of neon. The volt drop would be $(134 \times 10) + 180 = 1{,}520$ volts.

A glance at the table shows that as the current through the discharge increases the volts across the tube go down. This is naturally unfortunate because there is nothing to prevent the current rising to catastrophic values unless the current is automatically limited by some external agency. This negative resistance effect is similar to that shown by the arc lamp.

The next important point to note is that the voltage required to start a discharge is greater than that required to maintain it. In the example we have just considered, in which a little over 1,500 volts is required to run the discharge when once started, somewhere about 5,000 volts R.M.S. are needed to start up the discharge. It is obvious that a tube designed to run at 1,500 volts would pass hundreds of amperes if 5,000 volts were permanently applied to it. The automatic limitation of the current can be achieved by using a choke coil in the primary of the transformer, or better, by designing transformers with magnetic leakage, so that the voltage automatically drops as soon as the tube strikes up and the discharge begins to pass.

FACTORS AFFECTING THE LIFE OF TUBES.

We must now consider more carefully the phenomena in the immediate neighbourhood of the cathode and their influence on the behaviour and design of discharge tubes. As already stated, this largely determines the life of a tube for the following reasons:—

During the passage of a discharge a phenomenon known as cathodic sputtering takes place, which is the more vigorous the higher the cathode fall. This is something akin to evaporation, only instead of being due to the metal being at a high temperature it is produced by the impact of positively charged gas ions at the surface of the cathode. After a time this results in the formation of a film of metal on the glass walls surrounding the cathode,

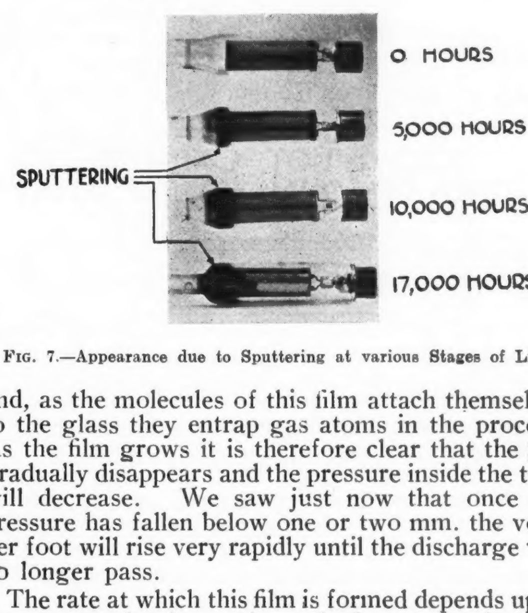


FIG. 7.—Appearance due to Sputtering at various Stages of Life.

and, as the molecules of this film attach themselves to the glass they entrap gas atoms in the process. As the film grows it is therefore clear that the gas gradually disappears and the pressure inside the tube will decrease. We saw just now that once the pressure has fallen below one or two mm. the volts per foot will rise very rapidly until the discharge will no longer pass.

The rate at which this film is formed depends upon the current density at the cathode, so that for any given electrode size there will be a corresponding value of the current at which the tube will give a reasonable life.

How is the light output from the tubes influenced? The luminous efficiency is low at high pressures of gas. As the pressure is reduced the efficiency increases until a maximum is reached, after which it falls off very rapidly. The pressure for maximum efficiency depends on various factors—but with neon it is round about $\frac{1}{2}$ mm. of mercury.

Naturally one would wish to work as near this pressure as possible, but considerations of the sputtering, which increases very rapidly as the pressure decreases, forces the use of higher pressure than this. In advertisement sign tubes, when very long lengths are required, pressures of several mm. of mercury are generally used.

So far as concerns the total light given by a tube, it may be said roughly that in the case of neon, for example, the candle-power increases proportionally to the energy dissipated in the discharge itself. Since the voltage across the tube decreases slightly with increasing current, it follows that as the current is increased the resulting light is not quite so great as would be expected if it was strictly proportional to the current.

Hot Cathode Tubes.

The discharge tubes which we have been considering up to now, although ideal for advertisement signs where we want to see the long sources of light themselves, are not of so much value for general illumination purposes, where we usually hide the source of light itself and allow its rays to illuminate and reveal the surrounding objects. This is, firstly, because these tubes require high voltages and, secondly, because of the relatively small amount of light which they yield per foot of tube. This means that for street lighting or floodlighting an inconvenient length would be required to afford adequate illumination. Nevertheless the old Moore tubes were used in long lengths for interior lighting, and similar tubes are indeed of real value for producing special effects. But at present we do not know how to employ them economically where concentration of the light is needed by means of optical systems. You will remind me that the object of good street lighting is to keep down the brightness of the sources themselves—and long lengths of these low brilliancy tubes should therefore yield an attractive and efficient street-lighting system. However, a way of employing them effectively and efficiently for this purpose has yet to be developed.

Clearly what is needed for these purposes is a tube which will give 10 or 100 times the light output per foot run. Now the light increases as the current increases, but we cannot increase the current in cold cathode tubes without shortening the life of the tube owing to sputtering—unless we do it by increasing the area of the electrodes. But to do this effectively we should need electrodes 100 times the area of the present ones—which is out of the question.

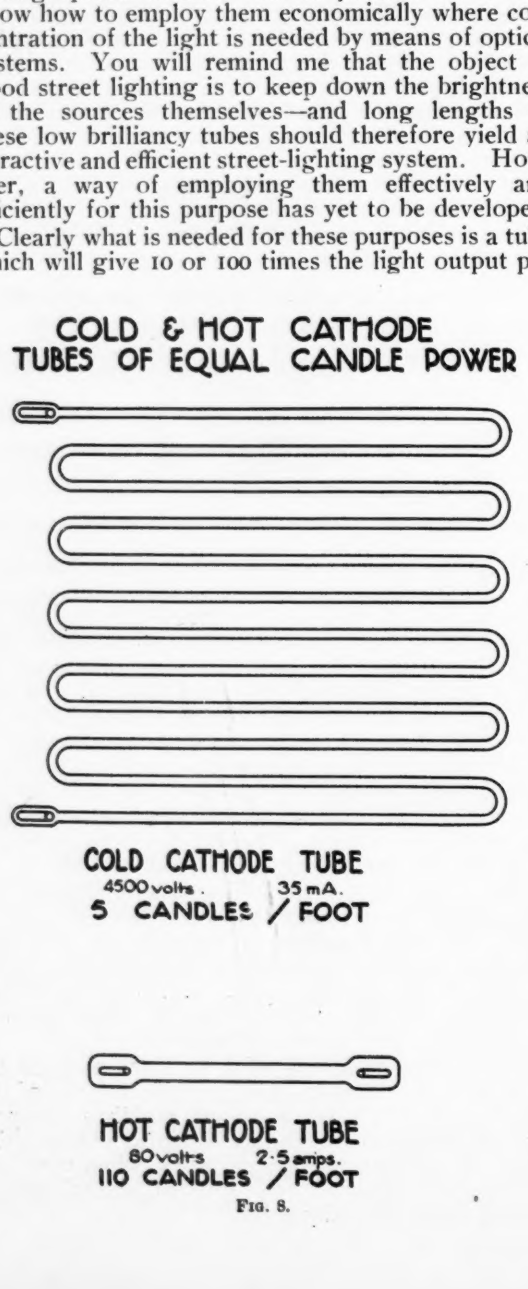


Fig. 8.

If we could pass a heavy current without increasing the size of the electrodes we should solve both our difficulties at one stroke, because, as we have already seen, the volt drop per foot will be greatly reduced—and the shorter length would enable us to use lower voltages.

The solution which was put forward by Pirani in Berlin and by the General Electric Company of America consists in the application of the well-known fact that if the cathode is heated to a temperature at which it will emit electrons freely, then the cathode fall will be greatly reduced, and large currents passed without serious sputtering taking place.

Tubes embodying these principles form a new and separate class which we will call hot cathode. What now follows will mainly concern tubes of this type. Amongst them are to be found some of the latest and most interesting developments.

In them the electrodes consist of alkaline earth oxides which can be heated electrically like small filaments. Alternatively they may be formed of small oxide-coated metal cylinders which can be indirectly heated by a tungsten spiral inside, much as the cathodes in indirectly heated cathode valves.

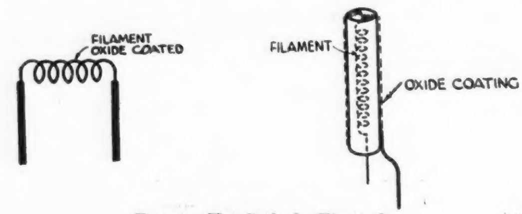


Fig. 9.—Hot Cathode Electrodes.

By the use of these electrodes the cathode fall is greatly reduced and is, in fact, only about 25 to 30 volts. As a result of this, much larger currents can be passed without appreciable sputtering taking place. In fact, the current can be increased some 30 or even 100 times that which would be possible with ordinary cold cathodes. The current is now only limited by the heat developed by the discharge which, if excessive, would soften the glass walls. As a result of the high current, the voltage drop per foot of the positive column is now much less than in the case of the cold cathode tubes; also as already stated, the cathode fall is greatly reduced. In consequence the running voltage is so small that the discharge can be maintained on the ordinary supply voltages, and no step-up transformer is needed. A choke to limit the current is, however, necessary and a small filament - heating transformer to supply current for the electrodes. The starting potential of these tubes is still rather high, and so it is generally necessary to supply a momentary high voltage to start the discharge. This is most easily done by means of a small high-frequency Tesla coil.

The Gas.

From what gases or vapours are we free to choose for use in discharge tubes?

Firstly, the gas must, when excited by the discharge, emit a suitable spectrum. We must remember that the light we see is not the whole of the radiation that is emitted by the gas. There are the ultra-violet and infra-red regions to which some gases devote a great deal of their radiant energy.

Such gases are of little use for efficient light-sources, though some may be used occasionally if special colours are desired. One example is carbon dioxide, which, although not efficient, gives a fine white light, very similar to daylight; another is hydrogen, which gives a beautiful pink colour, but is extremely inefficient as a producer of light.

Some gases and vapours which might be used in discharge tubes

HYDROGEN	HELIUM	LITHIUM	CALCIUM	MAGNESIUM
NITROGEN	NEON	SODIUM	STRONTIUM	ZINC
OXYGEN	ARGON	POTASSIUM	BARIUM	CADMIUM
	KRYPTON	RUBIDIUM		MERCURY
	XENON	CAESIUM		
		ELEMENT 87		

GALLIUM	PHOSPHORUS	SULPHUR	FLUORINE
INDIUM	ARSENIC	SELENIUM	CHLORINE
THALLIUM	ANTIMONY	TELLURIUM	BROMINE
	BISMUTH		IODINE

Also compounds e.g.
CARBON MONOXIDE
CARBON DIOXIDE
CYANOGEN
SULPHUR DIOXIDE

FIG. 10.

Secondly, the gas or vapour must not decompose under the action of the discharge. For example. hydrogen sulphide does so, and when it breaks down sulphur is deposited on the glass walls.

Thirdly, the gas must not attack the glass or electrodes. For this reason fluorine or chlorine gas would be quite unsuitable.

Fourthly, when using a *vapour*—as distinct from a gas—as the main constituent, the vapour pressure must be appreciable (several tenths of a millimetre) at temperatures below the softening point of the glass. Thus the vapour of tin or boron would never do.

Fifthly, the colour of the glow, either alone or combined with that of other tubes, must be useful. We have already seen that most gases or vapours, when under the influence of the discharge, emit radiation in a few limited regions of the spectrum only. In this they differ radically from the incandescent tungsten-filament lamp, which emits all wavelengths of the visible spectrum. Thus sodium vapour emits much the greatest part of its light at a wavelength of about 5,890 in the yellow region, and only a minute amount in the green and blue regions. Sodium vapour alone is therefore likely to be limited in its use for general lighting, because the only colour it appears to call into existence in the object it illuminates is yellow. The molecules in the objects to be seen which would ordinarily reflect in the blue and green wavelengths are not suitably stimulated by sodium light, and the eye therefore misses the blue and green sensations. If, therefore, sodium is to be used at all generally in discharge tubes, it should be in conjunction with some other gas which will add to the sodium radiation other wavelengths—the sum total of which will give reasonably good colour rendering.

Sixthly, the voltage to strike the tube when starting up varies greatly with different gases. It is desirable that both this starting voltage as well as the running voltage should be low.

Lastly, the gas should not clean up easily on to the glass walls under the action of the discharge, otherwise we shall experience the same trouble as occurred with the original Moore tubes which had to have a more or less elaborate replenishing device for introducing fresh gas to make up for that which had become immobilized on the glass walls of the electrode chambers.

This appears an exacting list of requirements but we are still left with a number of possible gases and vapours from which to choose.

The following are examples:—

Gases	Neon ..	.. Red.
	Helium	.. Ivory white, but yellow in special glass.
	Nitrogen	.. Buff.
	Carbon dioxide	Daylight white.
	Argon, Krypton, Xenon	Not used alone but only in conjunction with other gases or vapours.
Vapours	Mercury	.. Blue to white according to pressure. Green in special glass.
	Sodium	.. Yellow.
	Cadmium	.. Greenish blue.
	Thallium	.. Green.
	Magnesium	.. Grass green.

A white light can be obtained from a neon tube in which a little mercury vapour is present—provided that just the correct quantity is maintained.

It will naturally be asked why cannot any desired hue of light be obtained by mixing in one tube any of these gases and vapours in the right proportions? Unfortunately the matter is not so simple as this. As already stated, each gas requires a unique value of voltage to stimulate it. If several gases or vapours are present in a tube together, in general, that requiring the lowest voltage to stimulate it will mask those which require higher voltages to stimulate them—unless indeed their voltages have closely the same value. Thus the characteristic colour of the gas requiring the lowest voltage to stimulate it will dominate the hue of the radiation.

For instance, it would seem to be a very attractive idea to use a mixture of sodium, mercury and neon in the same tube and combine their yellow, green, blue and red spectrum lines to obtain a good radiation. But for the reason given these will not work together in harness as we want them to. The willing horse does all the work.

This applies specially to the positive column. Near the cathode it frequently happens that when more than one gas is present, the characteristic colour of that requiring the higher ionization voltage will show up, although it is masked in other parts of the tube. If we think for a moment we can see the reason for this. The gas with the higher excitation voltage can be excited near the cathode because the cathode fall of voltage takes place over a very short distance, and the speeds of the electrons here are higher. Thus for mixtures, a gas can be excited in the cathode fall region which in the positive column remains relatively inert.

In what has just been said we have assumed that plenty of each gas is present. If, however, we consider a tube containing a gas, together with such a metal as mercury, which will evaporate as the tube gets hot, we find that at low temperatures the gas spectrum only will show, and at high temperatures only that of the mercury. But at some intermediate temperature both the gas and the vapour of mercury will be excited. The practical difficulty is to hold the temperature conditions in such a state of equilibrium that the radiation of both elements remains steady in the desired amounts.

POWER FACTOR.

Owing to the fact that the gas discharge does not obey Ohm's law, the wave form of the current or of the voltage across the tube is not a simple sine curve. Fig. 11 shows some typical oscillograms. In the case of a neon cold cathode tube it will be noticed that at the beginning of each cycle the voltage rises up to the value at which the discharge

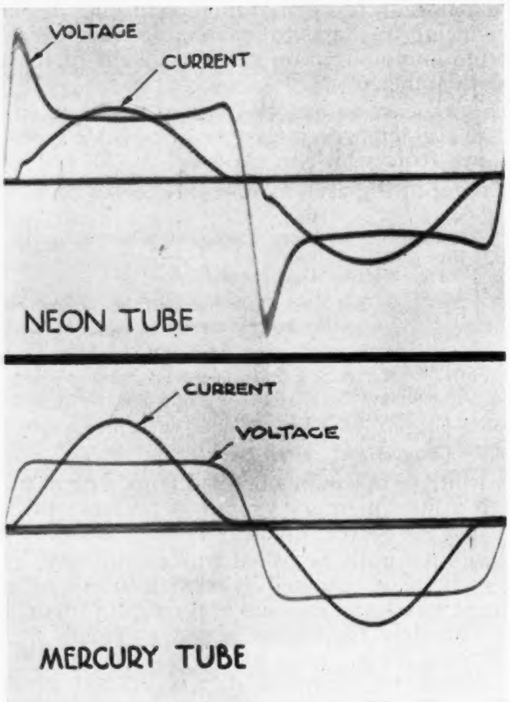


Fig. 11.—Oscillograms of Discharge Tubes.

strikes and then it rapidly falls to a steady value, finally dropping sharply to zero at the end of the half-cycle. Looking now at the oscillogram of the current, this of course remains zero until the voltage has risen to the striking value and then it rises, but only to fall to zero again just before the end of the half period. In the case of the mercury tube you will notice that the first peak is almost absent owing to the fact that the striking voltage is much nearer to the running voltage than in the case of neon. The oscillograms for hot cathode tubes are much the same, but the peak with neon is generally not so pronounced. The exact wave form depends on the type of tube and on the circuit conditions. How does this wave form affect the power factor?

If a supply voltage is applied to a simple circuit consisting of an inductance and capacity, the product of the current and voltage multiplied by the power factor gives, as everyone knows, the true watts dissipated in the circuit. When the applied voltage is sinusoidal, the power factor is readily calculated in terms of the values of the inductance and capacity, and it becomes unity when these values are zero, or bear a certain definite relation to one another. But if the sinusoidal potential is applied to a circuit not obeying Ohm's law then the power factor will not be unity, even if no inductance or capacity is in the circuit.

Engineers in the past became so accustomed to being able to assume that their wave forms were sinusoidal and their loads, for practical purposes, ordinary inductances or capacities, that the power factor became synonymous with (cos ϕ) the cosine of the angle by which the current lagged behind the voltage. They were apt to forget that the sinusoidal wave was only a very special case in the whole power-factor problem. With discharge tubes, whilst we can and do use condensers to eliminate the current lag caused by the series choke, and thereby cause the beginning and end of each current half-cycle to coincide with the beginning and end of its voltage half-cycle, yet owing to the considerable wave-form distortion produced by the discharge, the power factor will still be less than unity. Hence, as we add capacity to our circuit, the power factor improves up to a point, but then as we add more it begins to drop back again without reaching unity. It turns out in practice that a power factor of at least 0.8 can readily be obtained in this way with cold cathode tubes running on leakage transformers. With hot cathode tubes the same applies, and, in fact, even better correction (0.95 for example) can be achieved with some of the more important new types.

Successive Image Effect.

We hardly notice the 50-cycle alternations of supply voltage when applied to an ordinary incandescent lamp, because the filament does not seriously cool down between successive half-cycles. On the other hand, gas-discharge tubes follow the current changes more closely, and therefore the "successive image" effect of moving objects is more marked, and is sometimes a nuisance when objects are moving rapidly.

If a three-phase supply is available this effect can be practically eliminated by running nearby tubes on alternate phases. This, however, is not generally feasible, so that we have to consider what other means is available.

Suppose we construct the tube with two anodes at one end and a cathode at the other, and connect it up appropriately. It can be arranged that current will flow through the tube in the same direction at each half-cycle, but first through one-half of the circuit and then through the other. The effect of the inductance in the circuit is to cause the current half-cycles to overlap, and if its value is high enough it will practically eliminate the successive image effect. The only disadvantage of this system is that it needs so much gear for each tube.

The effect is one which must be reckoned with. My impression is that it is not so troublesome as the so-called "flicker" effect on 25-cycle supplies with ordinary lamps—but only experience under all conditions will settle this.

Photometry.

Complications of a serious kind arise when we try to think of the luminous output of coloured discharge tubes in terms of candle-power—for the standards of candle-power we use for comparison give white, not coloured light.

Some very broad issues arise here. There are those who claim that even when we have achieved, on the basis of the laws of physics, an accurate comparison of our coloured discharge lamps with our candle-power standards, the result is not a true gauge of the effectiveness of these light-sources to aid human vision in discriminating objects. It is suggested that physiologically one colour is better than another for seeing with, and particularly that if the coloured light is monochromatic, that is, restricted to one narrow band of the spectrum, the optical system of the eye can focus objects more accurately, and so get effectively more out of a candle than if the light-source emits over the whole spectrum. Whilst this is undoubtedly true in the discrimination of fine detail, there has yet been no proof that we should be justified, as it were, to multiply physical candle-power by a coloured light factor to turn them into a higher or a lower value of —shall we say—"Physiological" or "Effective" candles.

This would be equivalent to saying, for instance, that 50 candle-power of neon light is equal to 65 candle-power of daylight, or of tungsten light, and that we must therefore multiply up all our values

of neon lamp candle-power by this factor and give the neon lamp this advantage.

If such claims for monochromatism are made they should be discounted—if for no other reason than that strictly monochromatic illumination causes all objects to appear of the same colour. They differ only in brightness. The alleged greater effectiveness of discharge - tube illumination would only therefore be secured at the cost of complete distortion or elimination of the colour of objects. This would be too high a price to pay, except in a few special instances.

The basis of measurement of candle-power of these coloured sources in terms of our ordinary units is not yet established. For good or for ill the past has bequeathed to us a unit of light intensity based on sources which produce a continuous spectrum. Hitherto our sources of light, whether the sun or incandescent solids, emit light of all colours; the various sources differing, in that the proportions of light of the different colours are not equal.

Whilst it is true that these differences introduce certain difficulties when it is desired to compare the light-giving power of two such sources, to a high accuracy, yet no very serious difficulty is, in general, encountered by the individual observer.

Before passing on to consider the evaluation of the light-giving power of discharge lamps which only emit light of one or two colours, let us first examine a little in detail what is involved in making these measurements.

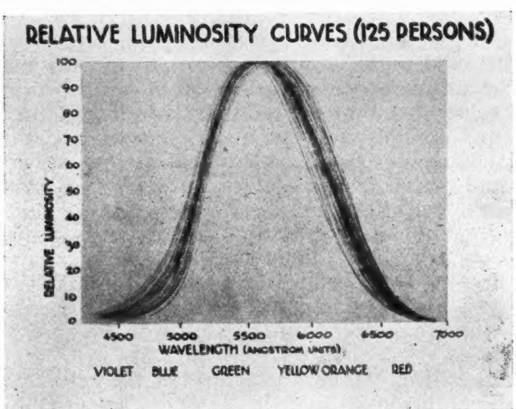


FIG. 12.

In Fig. 12* is shown a mass of curves, each one of which represents for one observer the brightness which a white surface would appear to have when a constant amount of radiant energy of different wavelengths falls upon the surface. Not only does the colour of the surface appear to change as the wavelength or frequency of the radiation changes, but also its brightness. The vertical ordinate of each of these curves at any point is proportional to the apparent brightness of the surface to one observer.

You will see how different these curves are liable to be for different observers by noting the spread on any vertical ordinate.

To compare the light-emitting powers of two incandescent bodies (say carbon filament and tungsten filament or two tungsten filaments at different temperatures) which differ in the proportion of light of different colours emitted, three methods are often employed, which in general yield a different result for any particular observer and also different results for different observers.

* Reproduced from Coblentz and Emerson. Bull. Bureau Stds., Vol. 14, p. 206 (1918).

The methods are: —

(*a*) The direct contrast method where two parts of a surface in juxtaposition are viewed simultaneously and the distances of the sources from the surface adjusted till both parts appear equally bright.

(*b*) The flicker method where the two sources illuminate two parts of a surface which are viewed in rapid succession: the position of the sources is adjusted until the flickering effect produced is reduced to a minimum.

(*c*) The filter method (using spectrophotometer).

In this method a filter is chosen which, when placed in front of a standard source, modifies the colour of the light in such a way that it appears to have the same colour as the other source whose candle-power is unknown.

In order to find the candle-power of the standard source modified by the filter, the following steps are necessary. The transmission of the filter for each wavelength is measured on a spectrophotometer, an instrument by which the contrast method of measurement is carried out without colour difference.

The next step is to determine for the standard source the relative amount of energy it radiates in each wavelength.

Lastly, the relative luminosity of the radiation averaged for a large number of observers for the different wavelengths is obtained. (This is determined from data illustrated by Fig. 12.)

This long series of observations is then utilized as follows: —

Wave-length A.U.	Filter transmission	Relative energy	Relative luminosity (visibility)	Product of Cols. 2, 3 and 4	Product of Cols. 3 and 4
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
4000	·52	0·77	·004	·0016	·0031
4200	·54	1·18	·040	·0255	·0472
4400	·57	1·71	·230	·2242	·3933
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Filter transmission $= \frac{X}{Y}$				Sum = X	Sum = Y

The sum of the products given in columns 5 and 6 are then determined and the ratio of the sum of column 5 to the sum of column 6 gives the transmission factor of the filter for the composite light of the standard source, and for the hypothetical average eye. Then the candle-power of the standard source combined with the filter is obtained from the known candle-power of the standard source above, multiplied by the transmission factor of the filter just determined. Then this combination of standard source and filter can be used as a new standard of closely the same colour as the unknown source, to measure the candle-power of the latter by the ordinary methods.

These three methods, when used in photometric laboratories of the highest class, utilizing the most refined methods, have not yielded agreement better than ± 2.0 per cent. when comparing a carbon lamp with a tungsten lamp.

Now when attempting to measure a sodium or neon discharge lamp the difficulties outlined above become very much enhanced. However, in principle the same procedure has to be adopted.

The properties of the filter chosen to modify the light from a tungsten lamp so that it closely matches the colour of a neon lamp are illustrated in Fig. 13.

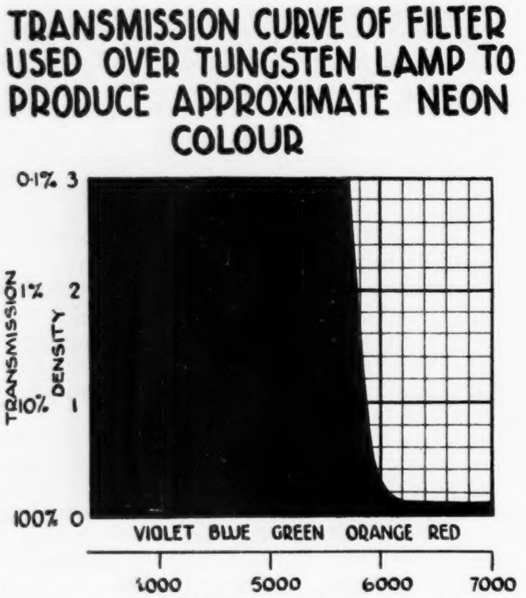


Fig. 13.

By determining the transmission factor of this filter for the light of the tungsten-filament lamp by all three of the above methods, and then utilizing this when making direct comparisons between tungsten and neon lamps, a reasonable approximation to the candle-power of the neon lamp can be made.

Factors Affecting Efficiency.

A word now on the subject of the efficiency of discharge tubes. We must think of this as influenced first by external and then by internal factors. The external factors are the losses in the series reactance, which is introduced to counteract the negative resistance of the tube. Also there are very small losses in the condensers used to correct the power factor. These electrical losses are, of course, obvious to every electrical engineer. The internal factors which influence the efficiency are much more numerous and complex. Some gases and vapours are intrinsically more efficient as light-sources than others, not only because they emit radiation at wavelengths lying in the parts of the visible spectrum to which the eye is most sensitive, but also because they emit comparatively little outside this range. A source which emits most of the energy in the visible region will naturally have a greater luminous efficiency than one which emits a considerable amount of infra-red or ultra-violet radiation. The fire-fly, for example, emits a continuous spectrum, but practically the whole of it lies between the green and the red limit of the spectrum. The maximum emission is in the yellow-green at 5700A. If you compare the energy distribution for the fire-fly and for an ordinary lamp, you will see the very large proportion of the energy which is emitted in the infra-red by the lamp. The fire-fly, on the other hand, restricts its radiation to the visible spectrum, and, in consequence, is an extremely efficient light-source.

It is, however, a very feeble one; about 1,600 fire-flies all glowing at the same time would be required to give one candle-power.

In the case of excited gases we have seen that, instead of continuous spectra, they emit radiation of certain wavelengths only. If all the energy supplied to a discharge tube were emitted at a wavelength of 5550A, corresponding to the peak of the relative luminosity curve of the eye, the luminous efficiency would be in the neighbourhood of 670 lumens per watt, compared with that of a 100-watt incandescent lamp with an efficiency of only 12 lumens per watt. Ninety-two per cent. of the energy supplied to the incandescent lamp is radiated in the non-luminous portions of the spectrum. For reasons which we need not review now this considerable waste in the infra-red is inevitable so long as the source of light is a hot body such, for example, as the filament of a lamp.

Let us now examine the radiation from one of these excited gases, taking a sodium lamp as the example. We find that, when it is burning under normal conditions, the energy emitted as infra red lines is only about one quarter of that emitted as the yellow D lines. The energy corresponding to the remaining lines in the visible and ultra-violet regions only amounts to a few per cent. Now from the visibility curve we find that sodium yellow light of wavelength 5890A. is about 78 per cent. as luminous as the green light corresponding to the peak at 5550A. Taking all these factors into consideration we might expect a very high luminous efficiency, somewhere about 360 lumens per watt. This has in fact been achieved at low intensities and under artificial conditions by Pirani, but it cannot be done practically. In practice it is, however, now possible to make 100-watt sodium lamps to have an efficiency of 70 lumens per watt, a great increase over the 12 lumens per watt of the corresponding incandescent lamp! But what is to account for the difference between the theoretical 360 and the practical 70 lumens per watt? The answer is that so far we have neglected all the losses in the tube itself. To understand these we must return to our discussion of the atomic processes going on in our tube. You will remember that when an electron flying through the gas collides with an atom, one of two things may happen. If its velocity is below a certain amount, the collision is elastic, while if it is greater than the critical value the atom is excited and may subsequently emit radiation. Previously we have studied the second of these processes, but what of the first? The electrons in an actual discharge tube are moving very fast and the result of all the elastic collisions is to speed up the atoms of the gas. The average velocity of the atoms in a gas is, of course, a gauge of its temperature, so that the result of the elastic collisions is that the gas gets hot. The gas, in turn, heats up the walls of the tube and this finally radiates in the infra-red region. There are many other more complicated processes going on at the same time but all end in the one way; valuable electrical energy is finally turned into heat at the glass walls and thus lost. One would therefore be inclined to say that what we want is a set of conditions under which no elastic collisions take place and none of these other wasteful processes occur. This is more or less desirable in the case of gases, but with some vapours, sodium in particular, it is not so. At room temperatures hardly any sodium would exist in the tube as vapour, so that in order to vaporize the required quantity, the tube must be kept hot. In order to obtain a highly efficient sodium tube it has to be lagged by surrounding it with an evacuated outer jacket to retain the heat; at the same time the elastic collisions and the other wasteful processes must be reduced. The most efficient tube will then be one in which the lagging is the greatest possible, and the heat-producing processes are reduced to the minimum required to maintain the inner tube at the required temperature. If this be chosen too low there will be insufficient sodium atoms present, while if it be too high the efficiency will drop because a greater proportion of the input energy is used up in the heat-producing processes.

This is a relatively simple case. With other vapours, such for example as mercury, other factors, some of them extremely important, must be considered. But an attempt to deal with these here would lead us now into too great detail.

RECENT DEVELOPMENTS.

As you will recognize, the development of hot cathode tubes has proceeded very quickly during the last year or so, and many types are now rapidly approaching a commercial stage. Let us briefly review some of the lamps and units which have reached various stages of development. If some particulars have to be omitted it is because it is difficult to discuss technical developments which are incomplete and not as yet properly incorporated in commercial products.

First of all, by placing neon and mercury tubes (the latter in either clear or green glass) in parabolic reflectors, very effective units are obtained suitable for the colour floodlighting of buildings, and the like. The efficiency of these is very greatly in excess of the ordinary incandescent lamps when combined with the colour filters which at present have to be used for this purpose. Then, by combining a neon and a mercury tube, the latter in a special fluorescent glass, a unit is obtained which emits a very pleasant light giving good colour rendering of objects. In this unit the tubes are enclosed behind opal-glass sheets, which mix and diffuse the light. Another development is the combination of hot cathode tubes with incandescent lamps. Neon tubes in this case tint the light and give it a rosy hue, blue mercury tubes give a daylight effect and also supply ultraviolet light if required. The advantage of this combination is that the incandescent lamps not only give useful light but, owing to their being in series with the discharge tubes, they act in place of choke coils.

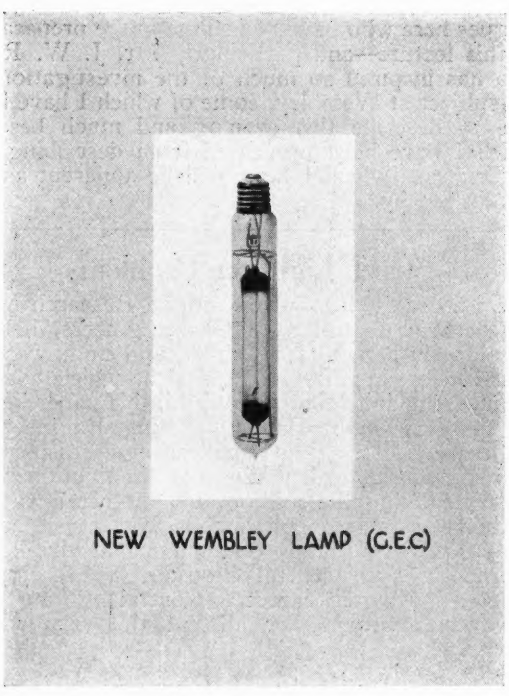


FIG. 14.

Secondly, we come to a very interesting new type of tube which has recently been developed at the G.E.C. Laboratories at Wembley. It is made at the moment in 400-watt units. This type, which is beginning to emerge from its experimental stage, consists of a vertical tube in which the discharge takes the form of an extremely brilliant narrow cord of light about 6 ins. high. The efficiency of a 400-watt lamp of this type is at present about 40 lumens per watt (as compared with 15 lumens per watt for a corresponding tungsten lamp), but higher values than this have been obtained in experimental tubes. The light from this lamp is deficient in red, but, if combined for instance with a neon tube, much better colour rendering would be obtained. It would seem that, when fully developed, this type of lamp should be particularly suitable for lighting streets and important thoroughfares. The street outside the Laboratories is at present illuminated entirely by these lamps, in which, however, the colour is not yet corrected. The effect is striking, though not yet as good as future developments can make it. This Wembley installation was first run at the beginning of July, 1932.

FIG. 15.

Thirdly, there is the sodium lamp, which emits practically only a pure yellow light. This type of lamp was first developed by Pirani, of the Osram Company, Berlin, whose researches showed how a glass could be made to withstand the attack of hot sodium vapour throughout hundreds of hours. A similar lamp of modified construction has also recently been developed by the Philips Company in Holland. There is an excellent section of road lighted with these in Holland and another in Zurich (which I have seen). The practical applications of the sodium tube have been specially studied by the Germans and the Dutch. The author showed early examples of sodium lamps two years ago at the Institution of Electrical Engineers — and further types have been under development. A type developed by Pirani, of which examples have recently been constructed at Wembley, already yields 70 lumens per watt. The sodium lamp lends itself to small wattage sizes of 80 to 150 watts, but in view of the extreme colour distortion produced by the sodium lamp it is not very suitable at present for general lighting or even for lighting ordinary streets. It is, however, being tried for lighting stretches of arterial and country roads where the lack of good colour discrimination is of little importance and where the illumination is nearer those lower levels at which the eye in any case is not accustomed to distinguish colour. In

FIG. 16.—Discharge-tube Lighting. (G.E.C., Wembley.)

other words, if the illumination is so low that the cones of the retina are out of action and we are using only rod vision—it does not so much matter if the light is monochromatic.

As for the future, who would care to predict what possibilities lie in store for us, after we have seen the rapid progress which has taken place in this fascinating field during the last year? But of this

FIG. 17.—Early Pirani Form of Sodium Lamp.

one can feel sure—once these new tubes reach the commercial stage, the next developments must proceed along the lines of improving first the colour and then, still further, the efficiency. Furthermore, much effort will have to be spent on adapting the different types to the varied illumination requirements of street and building. Meanwhile we may be confident that further fundamental research will

FIG. 18.—Discharge-tube Lighting. (Philips, Holland.)

reveal the possibilities of other new types of lamp, for many avenues still lie open to be explored.

Ladies and Gentlemen—I owe much to my colleagues here who have helped me in the preparation of this lecture—and particularly Mr. J. W. Ryde, who has inspired so much of the investigation on the subject at Wembley, some of which I have been able to describe this evening and much besides, which I have been prevented from describing but the fruits of which I hope will be apparent as the months go by.

Street Lighting Problems

A feature at the fourth Autumn Research Meeting of the Institution of Gas Engineers, held in London during November 1st and 2nd, was the contribution by Mr. F. C. Smith, which covered ground similar to that reviewed in his paper before the Association of Public Lighting Engineers in September last. The application of iso-candle curves and the calculation of illumination were illustrated, and the author also discussed various methods of arranging lamps in streets, such as the use of pairs of lamps on columns at the kerbs, alternating with central lighting, as at present adopted in Regent Street. Central lighting was, however, approved for all but the very widest streets.

Institute of Physics

ELECTION OF NEW HON. SECRETARY.

Professor J. A. Crowther, M.A., Sc.D., F.Inst.P., has been elected Honorary Secretary of the Institute to succeed Professor A. O. Rankine, O.B.E., D.Sc., F.Inst.P. Professor Crowther was for many years a lecturer at Cambridge, and was appointed Professor of Physics in the University of Reading in 1924, and he is now also Dean of the faculty of Science of that University.

Literature on Lighting

(Abstracts of recent articles on Illumination and Photometry in the Technical Press)

(*Continued from Page 286, November, 1932*).

Abstracts are classified under the following headings: I, Radiation and General Physics; II, Photometry; III, Sources of Light; IV, Lighting Equipment; V, Applications of Light; VI, Miscellaneous. The following, whose initials appear under the items for which they were responsible, have already assisted in the compilation of abstracts: Miss E. S. Barclay-Smith, Mr. W. Barnett, Mr. S. S. Beggs, Mr. F. J. C. Brookes, Mr. H. Buckley, Mr. L. J. Collier, Mr. H. M. Cotterill, Mr. J. S. Dow, Dr. S. English, Dr. T. H. Harrison, Mr. C. A. Morton, Mr. G. S. Robinson, Mr. J. M. Waldram, Mr. W. C. M. Whittle and Mr. G. H. Wilson. Abstracts cover the month preceding the date of publication. When desired by readers we will gladly endeavour to obtain copies of journals containing any articles abstracted and will supply them at cost.—ED.

II.—PHOTOMETRY.

279. The Optics of Photometric Measurements. T. Smith.

Proc. Phy. Soc. (Lond.), 44, pp. 314-324, 1932.

This paper is connected chiefly with the difficult problem of finding reflection factors of transparent bodies, but opaque bodies and the transmission factors of translucent bodies are also considered. The influence of apertures which limit the light transmitted from the source to the photometer, and of the reflection and transmission coefficients of the specimen and apparatus used, including the source and the photometer themselves, on the quantities determining a photometric balance are discussed. The subject is treated mathematically, and the incorrectness of the assumption that the reflection from a sample of transparent material is independent of the direction of the light is demonstrated. T. H. H.

280. Researches in Photo-electric Photometry and Spectro-photometry. Pierre Fleury.

Rev. d'Optique, No. 10, *p.* 385, *October*, 1932.

(1) PRECAUTION TO BE TAKEN IN APPLYING THE INVERSE SQUARE LAW OR TALBOT'S LAW TO HIGH-PRECISION PHOTO-ELECTRIC PHOTOMETRY.

Details certain precautions necessary in the case of photo-electric photometry, due to different types of change of sensitivity of the cells.

(2) PHOTO-ELECTRIC PHOTOMETER FOR THE PRECISE MEASUREMENT OF SMALL AMOUNTS OF LUMINOUS FLUX.

Describes a photometer comprising a vacuum cell used in conjunction with a resistance of the order of 10^9 ohms and an electrometer system. It is stated to be capable of measuring flux of the order of 10^{-4} lumen to an accuracy of about 1 part in 1,000.

281. A Method of Measuring the Maximum Intensity of Light from Photoflash Lamps or from other Sources of Short Duration. W. E. Forsythe and M. A. Easley.

Rev. Sci. Insts., Vol. 3, *No.* 9, *pp.* 488-492, *September*, 1932.

A photo-electric method of photometry based on the use of a special highly sensitive caesium cell is described. F. J. C. B.

282. A New Trichromatic Colorimeter. R. A. Houstoun.

Trans. Opt. Soc., Vol. XXXIII, No. 5, *pp.* 199-208, 1931-1932.

The design and construction of the instrument, which is on a new principle, are described. The intensity of the comparison field is altered by an iris diaphragm, and the colour by moving a magenta-yellow and a blue-magenta filter relatively to one another. Results obtained with the instrument are presented. F. J. C. B.

283. Note on the Correction of the Luminosities of Colorimetric Units. T. Smith.

Trans. Opt. Soc., Vol. XXXIII, No. 5, *pp.* 231-233, 1931-1932.

The trial-and-error method of correcting observed luminosities, in order to be consistent with the standard visibility function, may be replaced by the direct method described. F. J. C. B.

III.—SOURCES OF LIGHT.

284. The Tungsten Lamp. W. E. Forsythe and E. M. Watson.

Journal of the Franklin Institute, Vol. 213, *No.* 6, *pp.* 623-637, *June*, 1932.

The article traces briefly the development of the incandescent electric lamp and illustrates the advantages of the tungsten filament. The more important developments in the manufacture and use of tungsten filaments and the various factors to which the efficiency of the modern tungsten lamp is due, are discussed. L. J. C.

285. Illumination Derived from Commercial Electric Lamps. W. Pahle.

E.T.Z., No. 15, *pp.* 353-357, *April 14th*, 1932.

The author presents records of the illumination and distribution of light from a number of ordinary commercial lamps. The methods of measurement are described, and the illumination obtained is shown to be in good agreement with the desirable values for artificial lighting specified in the rules of the D.B.G. The influence of the shape and of the materials used in the construction of the lamps on the distribution of light is also discussed. L. J. C.

286. Economical Circuit for Pointolite Lamps. C. Arnaud.

Rev. d'Optique, No. 10, *p.* 412, *October*, 1932.

Describes a circuit consisting of an auto-transformer with two tappings, for starting and running, which avoids the large losses associated with the resistance generally used with pointolite lamps. J. M. W.

287. A New Mercury-vapour Lamp for Laboratory Use. Isay Balinkin and D. A. Wells.

Rev. Sci. Insts., Vol. 3, *No.* 7, *pp.* 388-391, *July*, 1932.

The lamp described fulfils the following requirements: (1) simplicity of construction, (2) compactness, (3) ease of starting, (4) steady operation, (5) high intensity, (6) long life. F. J. C. B.

288. Electrodeless Discharge and Sources of Monochromatic Light. Felix Esclangon.

Rev. d'Optique, No. 10, *p.* 399, *October*, 1932.

Describes an apparatus comprising an oscillator of 300 watts capacity operating at 10 metres wavelength, in the coil of which are placed discharge tubes without electrodes. Spectra of suitable gases and metals having intense lines easily separated are produced. J. M. W.

289. Dustless Cleaning of Arc Lamps. Anon.

El. World, 100, *p*. 526, *October 15th*, 1932.

An apparatus is described which enables arc lamps to be cleaned with complete absence of danger to the repairers from dust. W. C. M. W.

V.—APPLICATIONS OF LIGHT.

290. Leading with Light. A. L. Powell.

El. World, 100, *pp*. 458-464, *October 1st*, 1932.

The author gives a short history of the progress of lighting from the times of the first electric lamps to the present day. A number of photographs showing the diverse ways in which light is now utilized is included. W. C. M. W.

291. Investigation of Glare Phenomena Depending on Physically Measurable Quantities for Motor-car Headlights. M. Woolf.

Licht und Lampe, 18, *p*. 278, 1932; 19, *p*. 296, 1932; 20, *p*. 309, 1932.

Investigations to determine (1) what physical properties of headlights and light-sources are of importance in glare, and in what way glare depends on these properties, (2) how far the results of other glare investigations are applicable to headlights. E. S. B-S.

292. A New Contribution to the Relation between Space Brightness and Illumination. W. Arndt.

Licht und Lampe, 21, *p*. 218, 1932.

A discussion of the physical relation between space brightness and illumination and their interpretation from a physiological point of view. E. S. B-S.

293. Street Lighting. Anon.

Elect., 109, *p*. 556, *October 28th*, 1932.

Particulars are given of a new installation of centrally suspended lanterns at Clacton-on-Sea, together with photometric results obtained. C. A. M.

294. Outdoor Lighting. Anon.

Elect., 109, *pp*. 486-7, *October 14th*, 1932.

Two instances, with photographs, of recent installations in London are given. One is a new flashing sign at the London Pavilion, in which cold-cathode lamps are used. The other shows the use of a track reflector with definite cut-off, which has resulted in a reduction in the number of fittings required. C. A. M.

295. Night Sky Writing. Anon.

Elect., 109, *p*. 609, *November 11th*, 1932.

A description, with a photograph, is given of the optical and electrical details of the Savage sky-writing projector. Best results of visibility are obtained on a background of cumulus cloud at a height of about 5,000 ft. In these conditions projection is visible over an area of seven or eight square miles. 16 kw. are consumed. C. A. M.

296. Display Windows.

Elect., 109, *p*. 649, *November 18th*, 1932.

A description of various lighting arrangements that are employed in ground-floor display windows at Messrs. Selfridges & Co. Ltd. The general method adopted was the showing of objects in silhouette against an illuminated background. In some cases coloured light was used. In one window where dimmers are employed the load is over 10 kw. C. A. M.

297. The Economics of Illumination in Silk and Artificial Silk Mills. N. Goldstern and F. Putnoky.

Licht und Lampe, 23, *p*. 347, 1932.

Discusses the special lighting required for these mills owing to the reflective power of silk. E. S. B-S.

298. Floodlighting. T. E. Ritchie.

G.E.C. Journal, III, *pp*. 167-178, *November*, 1932.

This article deals in detail with various criticisms of floodlighting that took place in connection with the I.C.I. in this country last autumn. Reflection factors of the surfaces of a number of buildings in London are given before and after cleaning. Photographs given include two showing the floodlighting of the ancient Greek Temples in Athens. C. A. M.

299. Art Gallery Lighting. D. W. Prideaux.

Light, 2, *No*. 8, *p*. 12, *September*, 1932.

Details with photographs are given of a laylight equipment for an art gallery. C. A. M.

300. Glazed Kid Sorted Easier by Daylight Lamps. J. W. Gerard.

El. World, 100, *p*. 605, *October 29th*, 1932.

200-watt daylight blue lamps are used in place of daylight having a northerly aspect for grading glazed kid leather for use in shoemaking. Show-window type reflectors are placed behind ground-glass screens, and an additional blue-tinted screen is used to simulate daylight. Better grading is claimed than is obtainable with natural daylight. W. C. M. W.

301. Unilever House. Anon.

Elect., 109, *pp*. 635-6, *November 18th*, 1932.

The lighting at Unilever House has been installed as part of the architectural scheme. Details, with photographs, are given. C. A. M.

302. Illumination Values in Train Lighting. F. W. Benton.

World Power, 18, *pp*. 218-221, *October*, 1932.

Details are given of the results of a recent investigation into the illumination values existing on four British railways, both on main line and suburban services. C. A. M.

303. Micro-Reflectors. J. Flügge.

Licht und Lampe, 20, *p*. 307; 21, *p*. 321, 1932.

Different methods of lighting microscopes for the various objects to be examined and for the different magnifications used are discussed. Some of the more recent types of lighting appliances are described. E. S. B-S.

VI.—MISCELLANEOUS.

304. The Penetration of Daylight in the Sea. E. O. Hulburt.

J. Opt. Soc. Am., 22, *pp*. 408-417, 1932.

During descents into the sea in a hollow sphere with a quartz window to depths of over 1,400 ft., Beebe observed that the colour of the water illuminated by the sun was a pure blue. He measured illuminations down to 800 ft. At 800 ft. the spectrum was a narrow band at 520 $m\mu$ (vivid transparent blue colour), in agreement with the Raman-Einstein-Smoluchowski theory of scattering of light. At 600 ft. he could see and recognize fish. Below 1,250 ft. not an organism was seen. He observed and calculated brightnesses (as calculated below) of the water, which, on account of scattering, was almost uniformly bright—like a blue fog.

Depth. Feet.	Observed horizontal brightness. Candles per sq. ft.	Calculated horizontal brightness. Candles per sq. ft.
50	10·4	44·4
200	0·41	14·4
500	0·02	3·5
800	0·02	0·8

A theory developed to explain the discrepancy between observed and calculated values, assumes a proportion of 25 millionths of the volume of the surface water being occupied by opaque material. T. H. H.

305. Progress in the Photography of the Aurora Borealis. Carl Störmer (Oslo).

Phys. Zeits, 33, *pp.* 543-544, *July*, 1932.

Co-operation of German and Norwegian scientific societies is enabling further work to be done in the instantaneous photographing of the Aurora Borealis during the winter season at the Aurora-Observatory at Tromsö. The intrinsic brilliancy of the Aurora is low, and the rapid changes in its configuration constitute difficulties. With improved objective lenses and more rapid photographic plates, it is now possible to obtain photographs with exposures of under ½ sec. Useful cinematographic results (at low-speed) can also now be obtained. Results at different stations show that the height of the Aurora is about 40 miles; hence its behaviour should throw some light upon the Heaviside layer. Colour-photographs can be obtained. There are some hitherto unsuspected nitrogen spectral lines in the near infra-red. T. H. H.

306. Intensity, Area and Distance of Visual Stimulus. Ellis Freeman.

J. Opt. Soc. Am., 22, *pp.* 402-407, 1932.

This paper deals with the response of the eye, when dark-adapted, to the minimum visible intensities. The minimum illumination visible depends upon the angular size of the area illuminated, and apparently to some extent upon the distance of the eye from the area illuminated. Numerical results are given. T. H. H.

307. The Cathode Sputterings of Beryllium and Aluminium in Helium. P. D. Kueck and A. Keith Brewer.

Ref. Sci. Insts., *Vol.* 3, *Nos.* 8, *pp.* 427-429, *August*, 1932.

In the course of the investigation it was found that the relative number of aluminium to beryllium atoms sputtered under identical conditions is 1.5 to 1, the thickness of the depositing film 2.5 to 1, and the light-absorbing power 10 to 1. F. J. C. B.

REVIEWS OF BOOKS AND PUBLICATIONS RECEIVED

PROCEEDINGS OF THE INTERNATIONAL ILLUMINATION CONGRESS, 1931. (2 *Vols.*, *pp.* 1,511 + *XX. Edited by Dr. W. S. Stiles.*)

INTERNATIONAL ILLUMINATION CONGRESS, 1931; (32, Victoria Street, S.W.1. Price 20s. per Volume.)

These two impressive volumes contain the 103 papers read at the various sessions of the Illumination Congress held at different centres in Great Britain during September of last year. An account of the various meetings has already appeared in this journal, so that there is no necessity to refer in any detail (even if this were possible) to the contents of the various papers. All that can be done is to give a general idea of the way in which the editor and publishers have carried out the very difficult task of producing such a vast mass of material in a form which makes it attractive to all who are interested in the subject of lighting, and convenient as a work of reference to those who keep it on their shelves as part of their literary "stock-in-trade."

The order in which the papers were presented at the meetings has not been followed in the volumes, but each volume has at the beginning a complete list of the papers, arranged according to sessions, so that it is an easy task to turn to all those papers which refer to any given subject. In passing, it may be mentioned that the laudable system of having a single pagination running through both volumes has been adopted.

The papers are, of course, printed in the original language in which they were written, either English, French or German (one is in Italian), but each is preceded by an adequate summary, and this summary is, in every case, printed in all three languages.

The index to the whole publication must have given the editor much food for thought. A good index to the contents of the papers could not have occupied less than twenty to thirty pages, and the preparation of such an index would have been a very heavy task indeed. The alternative system, and that actually adopted, is an index in which the subject matter of each paper is expressed in a few words (often the title of the paper), and these "entry phrases" have then been indexed in the ordinary way. By this means it should not be difficult for an enquirer to find, with very little labour, the particular paper of which he is in need when interested in any particular subject.

As is well stated in the Foreword, "many of the papers contain original matter of high merit. Others summarize current practice in different parts of the field of illumination." It will probably be a disappointment to many, especially those who listened to the very valuable discussions which took place at some of the sessions, that no place has been found in the proceedings for even a résumé of these discussions. At a moderate estimate, however, such a report could not have added less than between 200 and 250 pages to the already very bulky volumes before us, and one must regretfully conclude that the Council took the only practicable course in deciding to omit any record of the discussions.

With regard to the way in which the volumes have been printed and arranged it is difficult to speak too highly. The fact that the printing was carried out by the Cambridge University Press is in itself sufficient guarantee that the work has been well done, but the more closely these volumes are examined the more it becomes apparent that neither editor nor printers have spared any pains to make the publication as nearly perfect as one could hope. An example of this occurs at the very beginning of Vol. I, where a remarkably clear group photograph of the 156 members assembled at Cambridge is given. A most careful examination of the key to this photograph has failed to reveal a single error either of name or even initial—and this, although admittedly a matter of detail, is an achievement of no mean order, and an indication of the care which has clearly been lavished on the whole publication. Printer's errors seem to be entirely absent, or at least so few as to to escape detection at a single reading. The mathematics has been very well set out, and this fact, combined with the excellent arrangement of the numerous diagrams and tables in the letterpress, makes the pages a pleasure to look at, as well as easy to read.

The paper used for the letterpress is good, and the many half-tone blocks are printed on a surface-coated paper which gives excellent results, even with the very fine screens sometimes employed. The volumes are strongly bound in dark blue buckram, gilt-lettered on the back, and can take their proper place on any bookshelf of permanent technical literature. The price can only have been made possible by heavy subvention from the general funds of the Congress.

It is understood that the Proceedings of the International Commission on Illumination (8th session), held immediately after the sessions covered by the present volumes, will shortly be produced in a third volume uniform in size and price with those just reviewed. It may not be inappropriate here to quote the concluding sentence in the Foreword to these volumes, where the writers express the hope that "they will inspire other countries, not yet formally affiliated with the activities of the International Commission on Illumination, to throw their influence and their genius into the task which the Commission has set itself."

Exhibits Illustrating Progress in Illumination

AT the Opening Meeting of the Illuminating Engineering Society, held at the E.L.M.A. Lighting Service Bureau (2, Savoy Hill, London, W.C.), on October 11th, there was, as reported in our last issue, an excellent all-round display. We now take the opportunity to describe the exhibits more fully.

There were in all 14 items on the list. The first of these took the form of a few words from Mr. W. J. Jones, referring to the extensions of the Bureau, in which numerous new and effective demonstrations have now been staged. As, however, a description of the new premises appeared in our last number,* it is not necessary to say more on this subject.

The exhibits fall naturally into three main classes —lamps, photometers and fittings, though there were also several special items that fall outside these divisions, such as the striking new form of "cinema-sign," described by Mr. A. W. Beuttell, and several devices enabling the passage of rays of light through glassware to be traced and demonstrated.

New Types of Lamps.

Mr. K. V. Mackenzie (General Electric Co. Ltd.) presented several types of incandescent electric lamps.

The first exhibit was a **500-watt photographic lamp** and reflector, which have been specially designed for use by amateur and professional photographers. The lamp is of high efficiency, running at 23 lumens per watt in the low-volt range and 21 lumens per watt in the high-volt range. It has a draped filament, which makes it suitable for burning at any angle, and is fitted with an E.S. cap. A small 100-mm. diameter internally frosted bulb is used.

The reflector is intended for providing an intense light for indoor photography. It is constructed of aluminium, having a highly diffusible sand-blasted surface inside, and finished in crystalline black enamel. The reflector is mounted on a short pillar enclosed by a heat-insulating wooden handle, a circular base being screwed to the lower end of the pillar. Tilting at any angle is effected by means of a knuckle joint and wing-nut, and a simple focussing device is fitted. The lamp screws into a shock-proof shrouded E.S. lampholder. The reflector is provided with 12 inches of rough rubber twin C.T.S. flexible cable, fitted with a 5-amp. 2-pin bakelite plug.

The second exhibit was a **3-kw. lighthouse lamp** of somewhat novel design, having three filaments in parallel. This lamp was designed primarily for the Lighthouse Authorities. There are three reasons for having the three 1,000-watt filaments in parallel, namely:—

(*a*) It suits the optical arrangement of the Lighthouse Authorities.

(*b*) If one filament breaks down the other two remain on circuit.

(*c*) By having a lower current on each filament one gets a quicker nigrescence or "rate of cooling," which is required if the lighthouse has to flash a code sign.

The lamp is only supplied in 80 or 100-volt types, and has an efficiency of 15.2 lumens per watt.

The third exhibit was a low-voltage lamp for use with the constant-potential **series system of boundary lighting for aerodromes.** This lamp is rated at 6.6 amps., is gasfilled, and fitted with an E.S. cap. It is of special interest because the installation recently laid down at Croydon is the first electric boundary-light system adopted in this country.

Mr. S. J. Patmore, who followed, described the **Osram 10-volt long series traction lamp.** He remarked that in the past, owing to technical difficulties, it had always been necessary to use in series four, five or six lamps of 100 to 130 volts each on traction circuits for the lighting of tramcars, trolley buses or electric trains—with the result that if one of the lamps in the series failed the entire number was temporarily put out of action, causing inconvenience and bad lighting in the vehicles.

The new Osram low-volt long series lamp is rated at 40 volts 40 watts, and is made to run in series of 15 lamps on 500 to 600-volt traction circuits. The lamp has been fitted with a fusible cutout, which consists of an aluminium strip placed across the two lead-in wires inside the bulb. One of these lead-in wires is insulated by means of a further strip of aluminium covered with an oxide solution. At 40 volts this oxide acts as an insulator, but on the breaking of the lamp filament the full open-circuit pressure of from 500 to 600 volts is across the break in the filament, thus causing a breakdown of the insulation of the cutout, which automatically short-circuits the lamp and allows the remaining 14 lamps in the series to keep alight.

This lamp is used in conjunction with the special G.E.C. patented short-circuiting holder, which enables the failed lamp to be removed from the circuit without interfering with the remaining lamps in the series, and at the same time prevents any possibility of arcing taking place in the lamp-holder during the removal or replacement of lamps.

The advantages of such a system are:—

1. More efficient lighting of the vehicle.
2. The low voltage of the lamp and its method of construction makes for a much more robust and reliable lamp.
3. A large reduction in maintenance costs.

Mr. F. G. Thomson (Philips Lamps Ltd.) contributed to the demonstration several of the latest products in electric lamp manufacture.

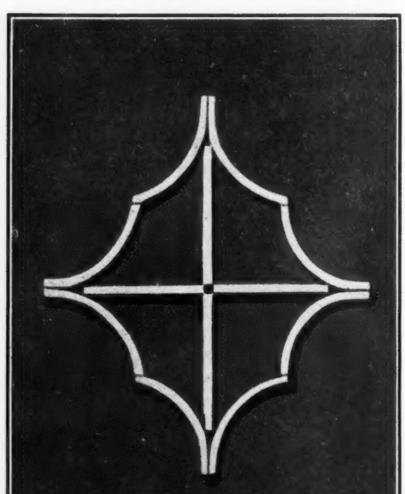


Fig. 1.—A Pattern in Luminous Tube Lamps, exhibited by Mr. F. G. Thomson.

An illuminated decorative design was exhibited, consisting of **straight and curved tubular lamps,** 20 ins. in length. By combining the straight and

* *Illum. Eng.*, Nov., 1932, pp. 303-304.

curved lamps a very effective design was created. The straight lamps were sprayed with a flame, the curved ones with an ordinary white diffusing finish. These colours, seen on a brown background, gave an idea of the decorative nature of these lamps.

The curved lamps were in two forms:—

(1) $\frac{1}{8}$ circumference of a circle, radius 25 ins.
(2) $\frac{1}{4}$ do. do. do. $12\frac{1}{2}$ ins.,

the diameter in each case being $1\frac{3}{16}$ ins. These lamps, he suggested, should prove of considerable value for architectural lighting.

The next item to be exhibited by Mr. Thomson was a **pear-shaped sign-lamp** sprayed in various colours. The feature of these lamps is the spraying, which is of a special character. It was pointed out that the sprayed glossy surface gives the lamps an attractive "colourful" appearance, even when not illuminated. Mr. Thomson remarked that the spraying would stand sea air, which was undoubtedly the greatest test for any coloured article.

The final exhibit by Mr. Thomson took the form of a **bulb for photographic flashlight work.** This bulb is operated from an ordinary 4-volt torch-lamp battery placed in a suitable reflector. A small element in the centre of the bulb, when ignited by the current, produced a very brilliant flash for a period of about 1/50th to 1/75th of a second. The actinic value of the flash is sufficient for photographic work, and it is stated that fine results have been obtained by the use of this new bulb.

A Novel Animated Sign.

Mr. A. W. Beuttell then threw on the screen a film illustrating the operation of the new **"movi-sign"** device, which excited general interest. The development of this new and effective sign is described in an explanatory leaflet, a copy of which has been kindly furnished by Mr. Beuttell. In this leaflet the various stages in the design of luminous signs composed of a large number of electric lamps is traced.

In its simplest form the electric sign consists merely of a number of lamps arranged on a board to make a given series of letters. Originally such signs were kept alight continuously, but it was easy to arrange a rotating contact device whereby the whole word or sentence or pattern could be alternately lighted up and extinguished—the familiar "flashing" sign.

From this elementary stage it was easy to proceed a step further, and to give an effect of animation by treating different parts of the design as separate items. If, for instance, a separate contact on a drum is furnished for each group of lamps forming a letter the letters can be made to light up in succession; or by arranging for fixed groups of lamps representing five different positions of the arm of a figure to be lighted up in succession by a moving contact, whilst the remainder of the figure is outlined permanently, one can produce the impression of a moving arm.

All such devices as the above involve the installation of a series of lamps adapted for the display of one particular sentence or picture only. The next step was the preparation of a standard network of lamps mounted in the form of a rectangle. By varying the combinations of lamps many different patterns or words can be produced. This naturally involves a separate contact for each single lamp. These contacts may be arranged within a rectangle of small dimensions, over which is placed a cardboard frame having apertures corresponding to the lamps which it is desired shall light up. Cardboard stencils bearing different pierced patterns, and thus giving rise to different pictures, can be substituted in a few minutes. A variety of advertising designs may thus be shown in succession on the same evening.

With a standard device of this kind, enabling any desired lettering or pattern to be shown, some degree of movement can also be introduced. The best example is the horizontal movement from left to right corresponding with moving words. Evidently such a movement can be produced by sliding a cardboard stencil over the series of contacts. By utilizing a continuous band of stencils series of sentences may be made to appear, as in the familiar sign giving the news of the day, a species of "luminous journal."

It will be observed, however, that even this device consists simply in the movement of a predetermined and definite form. Furthermore, in the case of all such devices, the effect is not truly cinematographic, as the requisite dark intervals for the luminous impression to die away cannot easily be furnished. There is therefore a tendency for a streak of light, like the tail of a comet, to follow the moving letters.

In principle, the transition from this stage to the production of a cinematographic effect seems elementary. All that one has to do is to evolve a series of stencils showing the necessary sequence of phases of the motion to be portrayed, and with the requisite dark intervals to eliminate persistence of vision. This is what is actually effected in this new device, the "movi-sign," but the practical difficulties are very serious, and would indeed have been insuperable with the methods formerly used. A network composed of glow-lamps is still adopted, the first model constructed utilizing 70 vertical rows of 50 lamps, or 3,500 in all. The films producing the cinematographic effects consist of either 300 or 600 cartons, all of which are the work of the artist Antonio Rubini. The designing artist works on a band of cardboard with a base network stamped on it, to which the designs must conform. The series passes in half a minute to about a minute. When the device is finally duplicated and transferred to the machine nearly a million openings, closings and circuits per minute may be effected!

Methods of Testing Lighting Glassware.

Mr. J. G. Holmes (Chance Brothers & Co. Ltd.) recalled that the use of smoke for demonstrating the characteristics of the light-distribution of glassware is widely known and commonly used. The basis of the method is to pass the beam to be examined through a narrow slit into tobacco smoke or chemical smoke, and, as different portions of the beam are allowed to pass through the slit, the whole beam can be examined in detail. This method is extremely adaptable for use with refracting glassware, but there is usually difficulty in applying it to reflecting glassware owing to a general masking of the reflected beam by the direct light. Smoke always has the disadvantages of impermanence and low illumination, which are of considerable importance if a photographic record of the beam is to be kept.

These disadvantages can be largely eliminated by the use of a flat white surface, which Mr. Holmes demonstrated. Frosted and opal glass, he added, had been tried, but he preferred a white card, with which the general illumination could be as much as fifty times greater than that given by smoke, with also a considerably decreased attenuation factor. Moreover, the reflection of light could be more easily studied by this method because the source of light could usually be effectively screened from the card.

If the card be slightly curved, the apparent attenuation can be reduced to zero, and uniform illumination is obtained over the whole length of

the card. Although this implies some slight restriction on the application of the method, it is a great advantage from the photographic point of view.

This demonstration arranged by Mr. Holmes showed the use of a curved card with a series of railway lenses and cover-glasses which are designed to give beams of different characteristics within close limits of accuracy. The detail of the beams can be examined, and it is immediately clear what faults are present and what corrections are necessary to the moulds in which the glass is pressed.

Photographs were exhibited to show some of the results obtained by this method with floodlight lenses and prismatic illuminating glassware.

Mr. J. M. Waldram also demonstrated the G.E.C. **"Ray-Path"** apparatus which was shown at the exhibition of the Association of Public Lighting Engineers at Blackpool in September last, and was illustrated in connection with the published account of that exhibition.*

This apparatus has been constructed in order to investigate the path of a ray of light which enters a piece of glassware of a transparent nature, such as a refractor or a silvered-glass reflector. It was known that the performance of such equipment could be seriously impaired by reason of light incorrectly deviated or trapped within the glass owing to faulty design or manufacture of prisms or of flutes in the case of fluted-glass reflectors.

The principle of operation is as follows: A sample of the glassware concerned is cut at right angles to the flutes of prisms under consideration and the cut surface ground flat. A piece of plane ground glass is held against that surface, preferably by adhesive applied only at two spots.

If a very narrow beam of light, such as the image of a slit, is allowed to fall on the glass and specimen at grazing incidence, then the path of the ray, both in the air and in the body of the glass after refraction, reflection, etc., at various surfaces, can be observed since it shows up on the ground surfaces.

The apparatus consists of a table upon which specimens can be placed, and a swinging projector so mounted in a bearing that the ray of light can be considered as radiating at any desired angle from a point in space. Adjustments and scales are provided to enable the point from which the ray emanates to occupy the position of the centre of the filament of the lamp as normally used with the reflector or refractor under test, or alternatively one side or the other of the filament or any other desired position.

All kinds of prismatic glassware and reflecting glassware can be tested, and such effects as incorrect prism formation, loss due to internal reflection, or by interference of one prism by its neighbour, or misalignment of internal and external prisms in pressed glassware, can be studied with great facility. It is possible by this means to observe sources of inefficiency which would be difficult to find by any other method.

New Illumination-Photometers.

Several new forms of illumination-photometers, or improvements of familiar ones, were exhibited.

Mr. J. Ockenden (Messrs. Everett, Edgcumbe & Co.) showed the latest type of **"luxometer,"** which has recently undergone important modifications, leading to increased precision, as well as to more convenient handling. The figure shows the complete equipment in its leather carrying-case.

In this photometer, balance is obtained between the brightness of a screen, illuminated by a self-contained comparison lamp and the surface under test. The internal illumination is varied by adjusting the inclination of the screen to the rays of light from the internal lamp by means of a very light milled head, which is held between the forefinger and thumb. This results in an almost logarithmic scale and facilitates balance. The comparison is

Fig. 2.—General View of Luxometer.

made by means of a half-silvered mirror, a novel feature being the production of an almost perfect "optical line" of demarcation between the two fields, so that entire disappearance can be obtained even if the colour of the lights differs considerably.

The range of the instrument is from 0.001 foot-candles to 3,000 foot-candles in five stages, the change being effected by means of calibrated neutral filters, which are interposed either between the comparison lamp and the internal screen, or between the observer's eye and the test surface, according to the range required.

A 4-volt accumulator is contained in the carrying-case, and a sensitive moving-coil voltmeter is provided for the adjustment of the voltage. In order that the position of the voltmeter pointer may be accurately set, a short-focus lens is attached to the instrument glass—an important feature in view of the fact that the candle-power of the comparison lamp is almost proportional to the fourth power of the applied voltage.

In conclusion, Mr. Ockenden stated that this instrument complies fully with the latest British Standards Specification for Portable Photometers.

An improved form of **Waldram Daylight Gauge** (which, it will be recalled, was exhibited at the opening meeting in 1931), which is now being made by Messrs. Everett, Edgcumbe & Co. Ltd., was also on view.

Two distinct novelties were the **Illumination-photometers** based on the use of **photo-electric cells,** exhibited by Mr. G. T. Winch (General Electric Co. Ltd.) and Mr. S. A. Williams (Standard Telephone Co.). The former exhibited and described the new G.E.C. portable instrument, which had previously been exhibited at the annual conference of the Association of Public Lighting Engineers in Blackpool.* The design of this instrument has been made possible by the development of the electrometer triode type of valve and a specially designed photo-cell. The latter is contained in a separate unit, complete with amplifying valves and range-changing devices all embedded in paraffin wax in order to maintain the requisite high degree of insulation. The metal containing-box screens the

* *Illum. Eng.*, October, 1932, p. 258.

* *Illum. Eng.*, October, 1932, p. 256.

amplifier from external electrical disturbances. The batteries and controlling gear are housed in a separate wooden box, which has a compartment housing the photo-electric cell when not in use.

The unit containing the photo-electric cell is connected to this box by means of flexible leads. Measurement is made by adjusting a potentiometer until the galvanometer deflection is zero, which indicates

FIG. 3.—The G.E.C. Photo-electric Photometer.

that the valve bridge is balanced. The potentiometer reading, multiplied by the calibration factor, gives the illumination in foot-candles. This apparatus is still in the experimental form. A new model, which will be considerably smaller, and will enable values down to 0.002 foot-candles to be measured, is now being designed.

The Weston Illuminometer, described by Mr. Williams, utilizes two essential items—a searching unit consisting of two Weston Photronic cells connected in parallel and mounted in a bakelite holder, and a microammeter, calibrated in foot-candles, to which the searching unit is connected by about 6 ft. of flexible wire. The microammeter is provided with three scales corresponding to ranges of 0–10, 0–50, and 0–250 foot-candles. The searching unit is merely placed at the spot where illumination is to be measured, and the value is recorded on the instrument dial in coot-candles (the appropriate scale being first put into operation).

The operation of this apparatus evidently depends very largely on the qualities of these new cells,

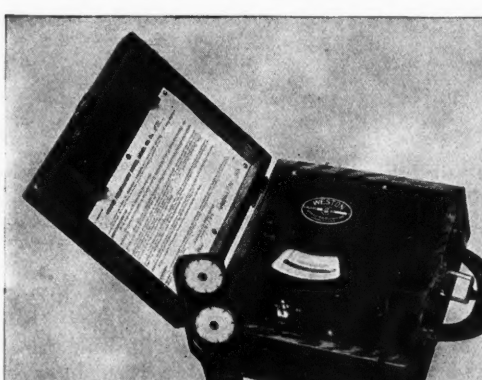


FIG. 4.—General View of Weston Illuminometer.

which consist of light-sensitive discs. They are electronic in action transforming light-energy into electrical energy without the use of any auxiliary power supply. When light rays strike the sensitized surface of the cell-plate electrons are emitted which build up a potential difference between this surface and the plate beneath it. When this circuit is connected through the microammeter current flows. A single cell delivers about 1.4 microamperes per foot-candle of illumination. The relation between illumination and current is practically linear, provided the external resistance is low in comparison with the cell-resistance. The cell, which does not contain any liquid or gas, appears not to be subject to any chemical or physical changes. Apparently the flow of a current does not harm the cell in any way. Exposure to sunlight has no prejudicial effect, nor does the cell deteriorate when inactive.

NEW TYPES OF PROJECTORS.

Mr. E. STROUD exhibited two new forms of Holophane units. One was a new form of flood projector for "close-up" floodlighting, which is octagonal in shape and formed with a series of totally reflecting prismatic panels. The panels consist of rectangles, equilateral triangles and a square, on the same principle as the Holophane "Hedralite" system. The reflecting prisms on each of the different panels are so arranged that when the series are assembled in the metal casing the optical focus is in the vertical axis of the unit. The panels being in relatively small sections are easily replaceable in case of fracture or for cleaning, and the reflecting surfaces being prismatic are permanent.

The projector gives a wide light-distribution over a 90°-zone, and is therefore very suitable to "close-up" floodlighting.

The casing is made of heavy-gauge spun metal, and is designed to accommodate the standard type gasfilled lamps, 1,000 to 1,500 watts, suspended vertically, cap up, with reference to the unit. Adequate ventilation and adjustment for the lamp filament are provided. The body is arranged on a stirrup-and-swivel base, enabling the beam to be adjusted to any angle in both the horizontal and vertical planes.

Examples of the latest types of Holophane heavy-duty units were also shown. This special range of units has been developed in the extensive and concentrating types of sizes suitable for 500-watt, also 1,000 watt gasfilled lamps. The outer casings are of mild steel, and the prismatic interior reflector is

FIG. 5.—Holophane Heavy-duty Industrial Reflector.

held in a special ring, enabling easy detachment of the reflector for maintenance purposes. The top of the canopy is detachable for easy wiring, and lampholders supplied are of the latest porcelain Home Office type. These units are regarded as exceptionally suitable for high-bay lighting problems and general power-station problems. It was stated that over 300 units of this type alone are at

FIG. 6.—The Holophane "Hedralite" Floodlight Projector.

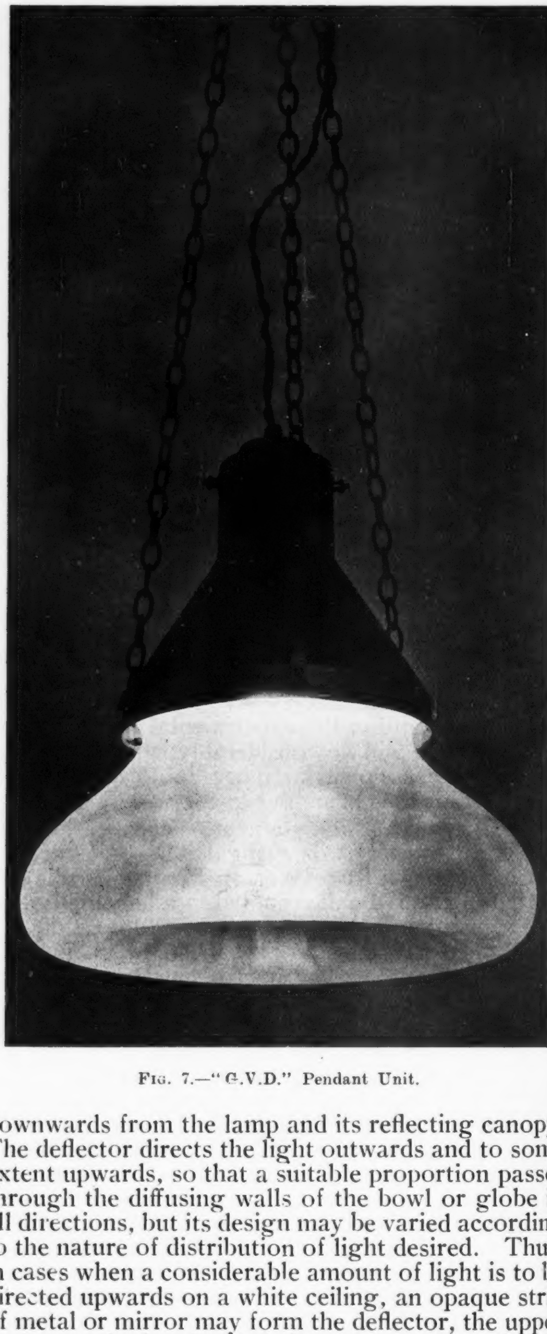


FIG. 7.—"G.V.D." Pendant Unit.

the moment being installed in the new Battersea Power Station for the London Power Company.

NEW FITTINGS.

Mr. E. J. STOCKWELL (Falk, Stadelmann & Co. Ltd.) introduced two exhibits. One of these, the new **"Globelite" fitting,** embodies a patent gallery, without set-screws or springs for supporting the globe, which is simply slipped over the gallery at an angle, and rests upon the flange. The result is most effective, as the gallery practically follows the outline of the globe, without imposing a deep-domed carrier, which is usual with the ordinary flange-fitting globes. This device is stocked in three sizes —8 ins., 10 ins. and 12 ins.—and can be obtained as a chain or rod pendant, a bracket or a ceiling fixture.

The other exhibit, an **adjustable cornice reflector,** takes the form of a white-enamelled trough, which was provided at each end with a slot, in which two screws were fitted to supporting brackets, thus permitting the light to be projected as best suited for the form of ceiling it was desired to light. The troughing is drilled along the centre base with holes at 3-in. centres, into which detachable lampholder brackets were fitted. This enables the same trough to be used either for 6-in., 9-in., 12-in., etc., centres, as desired. A special metalwork channelling is provided along the whole length of reflector, secured by bolts and milled-head nuts, and easily removable to accommodate the wiring. Where the surface of the cove is a bad reflector, provision is made on the bracket for an additional reflecting surface.

Mr. A. MURRAY COOMBS exhibited two forms of **"G.V.D." fittings,** in which improved methods of distributing light are embodied, frequently enabling results to be achieved with a single lamp in place of a number. These methods are at present exemplified mainly in pendant units, strip or panel lighting and lay-lighting. The pendant unit (Fig. 8) comprises a special diffusing-glass bowl attached to a reflector, entirely enclosing the lamp. A feature of this bowl is the indentation or concavity in the underside, the inner surface of which forms a conical or spherical detector on to which light is emitted downwards from the lamp and its reflecting canopy. The deflector directs the light outwards and to some extent upwards, so that a suitable proportion passes through the diffusing walls of the bowl or globe in all directions, but its design may be varied according to the nature of distribution of light desired. Thus, in cases when a considerable amount of light is to be directed upwards on a white ceiling, an opaque strip of metal or mirror may form the deflector, the upper regions of the bowl being now only slightly obscured. On the other hand, when light is intended to be directed mainly downwards and outwards the inner surface of the indentation may be highly polished and itself act as the deflector.

A typical pendant fitting is shown in Fig. 8, whilst Fig. 9 shows a pleasing form of semi-indirect pedestal unit.

In the case of trough or panel lighting a saving in energy-consumption is effected by using a single lamp or group of lamps at one or both ends of the trough or panel, with a reflector designed to throw the light in a concentrated beam along the trough, together with a curved deflector or series of deflectors arranged behind the panel, so as to deflect the rays of light from various parts of the beam evenly on to the strip or panel of diffusing material. In a similar way a vertical hollow translucent pillar can be illuminated throughout its entire length by a single powerful lamp in a concealed position at top or bottom of the pillar; conical or frusto-conical deflectors being mounted in suitable positions at various heights inside the pillar.

FIG. 8.—G.V.D. Indirect Pedestal Floor Standard.

One other important feature of this system of lighting is that, owing to the reflection and dispersion of light by these deflectors, comparatively thin and lightly diffusing glass may be used.

Mr. HOWARD LONG (Benjamin Electric Ltd.) had arranged to exhibit several new and improved types of fittings. These, unfortunately, arrived too late to be displayed at the meeting, but we illustrate herewith two types, the " Benflux " diffusing fitting and a re-designed shop-window trough. The former gives well-diffused light with a high efficiency. The lamp is shielded from view by an opalescent glass shade, and the upward component is re-directed by a " Crysteel " porcelain-enamelled reflector of the distributing type. Some light is emitted upwards to the ceiling through apertures in the top of the reflectors, which serve not only to afford ventilation but also to eliminate the unsightly effect of complete darkness overhead. A portion of the light emerg-

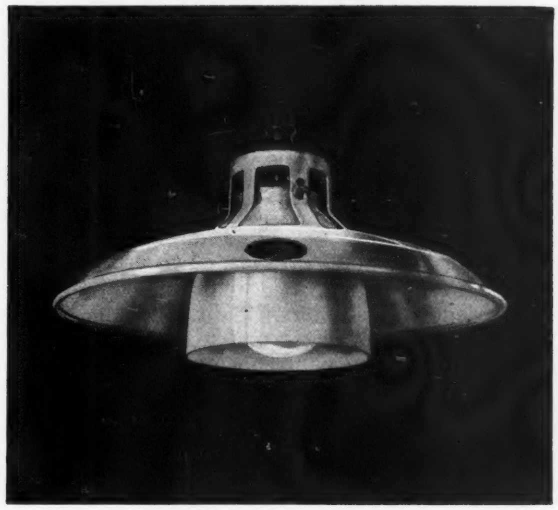


FIG. 9.—" Benflux " Diffusing Fitting.

ing through the apertures is also reflected by the top disc on to the upper side of the reflector, giving a pleasing effect. With this unit a wide spacing, i.e.,

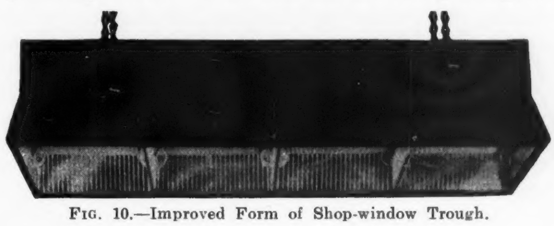


FIG. 10.—Improved Form of Shop-window Trough.

1.66 times the height of the unit above the working plane, may be adopted. Whilst intended primarily for use in schools, it is also suitable for libraries, offices and small shops, etc.

The shop-window trough illustrated in Fig. 11 has been re-designed, features being the increased reflecting surface and the introduction of mirror-partitions leading to improved efficiency. The separation of the lamps by means of the mirrored partitions renders it impossible to see the filaments when looking along the troughs—a manifest advantage in the case of island windows. There are two types, the " intensive " for shallow windows and the " extensive " for deeper windows are available. There are two sizes, intended for 60-watt and 100-watt lamps, but of identical external appearance.

Other novel fittings of an architectural type were exhibited by Mr. J. E. LANE (Siemens Electric Lamps and Supplies Ltd.).

Mr. J. M. BARNICOT (General Electric Co. Ltd.) exhibited some enclosed diffusing fittings of pleasing design, incorporating " Britalux " glassware of low absorption and British manufacture. The metal work was copper-finished in bronze colour, harmonizing well with the glassware. These fittings are made to standard diameters of 12 ins. and 16 ins., and for 100- to 300-watt lamps.

Mr. Barnicot also showed a " super-floodlight," developed primarily for heavy-duty work, such as railway yard lighting. This incorporated various new features. The floodlight is constructed of silicon-aluminium alloy and forms a total casting. Focussing is carried out by means of a positive-action device, operating in three planes, which is situated in the floodlight chimney, and is accessible under a hinged-cover lid. In the interior is a double parabolic one-piece pattern of silvered mirror, mounted on springs to minimize breakage and vibration. In addition, the lampholder includes an anti-vibration device, which also ensures that no damage can arise in the event of the lamp fouling the reflector.

Practical Street Lighting Demonstrations

TESTS of illumination and demonstrations of street lighting on a large scale have been instituted in the canton of Zurich by the electricity works supplying that area. These involve a semi-permanent installation along 300 metres of tree-sided, macadam-surfaced road, the regular illumination of two main roads and the experimental illumination, by luminous tubes, of an arterial road.

The demonstration section is primarily to enable the representatives of municipalities in the canton to undertake observations and measurements with different fittings, lamps and spacings as a preliminary to decisions regarding innovations in their street lighting. This stretch of road has exposed conductors along each side, supported by masts, placed 40 metres apart longitudinally, directly opposite one another, fitted with long-arm brackets on the road-centre side and mechanically connected by supporting span wires. Any group of lamps can be individually energised by switches. The total watt-consumption of the length of road has been fixed at 600 watts, or 2 watts per metre length, for each system operated. At present 75 and 150-watt lamps at spacings respectively of 80 and 40 metres are in use with six different systems of fittings, namely, (1) plain 75-watt lamps on bracket arms; (2) plain 150-watt lamps within clear glass globes; (3) Holophane two-way directional lanterns with 150-watt lamps; (4) "Shada," extensive-pattern reflectors with half-mirror 150-watt lamps; (5) a new design of "extensive" reflector and ordinary 150-watt lamps; (6) low-elevation lamps constructed in pursuance of the suggestions of Mr. E. Brenner, projecting light below the level of the pedestrian's eye up to at least 100 metres; the final pattern of fitting for this system is, however, not yet available.

Possibilities of street illumination on a larger scale are demonstrated on the 5-kilometre macadamised road connecting Lucerne city to Schlieren, along which, at heights varying from 8½ to 9 metres, centrally suspended between iron masts, various systems of lighting units are placed. One section with 300-watt lamps, supplemented by others at road crossings, tramway halts, etc., has Holophane two-way directional fittings, which radiate the light to the tops of the houses lining the road and produce a pleasing effect with apparently even illumination throughout the stretch. The consumption is at the rate of 4.6 watts per metre length of roadway. Another section has circular, extensive-pattern fittings using half-mirror lamps, and produces an almost glareless illumination, but with greater diversity factor than the foregoing stretch; there is also restriction of the illumination in a vertical plane to the first floor of the neighbouring houses, a limitation much appreciated by some of the dwellers in them! The consumption, using 300-watt lamps, is 4.2 watts per metre run. Adjacent to this section is a length of road devoid of houses, which has been intentionaly left unilluminated for the purpose of ascertaining the advisability of generally lighting country roads. This thoroughfare accommodates considerable traffic of a very diverse nature, embracing pedestrians, pedal and motor-bicycles, motor-propelled coaches, passenger cars and freight vehicles.

The Industriestrasse, from Altstetten to the gas works in Schlieren, in contrast to the last-mentioned roadway, is used mainly by fast-moving motor-vehicles. Along 1 kilometre length of this road illumination by means of 30 "Philora" luminous sodium gas tubes, consuming 100 watts each, and using energy at the rate of 3 watts per metre length, is furnished. These novel lamps produce a remarkably even illumination with absence of glare. The light emitted is approximately monochromatic, and the luminous efficiency is very high (stated to be from three to four times that of any ordinary form of incandescent lamp). It is claimed that the visibility is about six times that obtainable with the other systems with like consumption, and that the road can be traversed in safety by motor-cars without headlights.

A further set of four demonstrations, each visibly marked by an electrically lit letter sign (O to R) centrally placed, is being made on the road connecting Zurich to Wollishofen and Adliswil, the particulars being:—

Section O: Brackets carrying 75-watt lamps with twin-directional enamelled reflectors at 6-metre height, placed alternately on opposite sides of the way. The illumination is satisfactorily even and glare-free, but more powerful lamps were inadmissible, due to glare becoming excessive. The consumption of this, as well as sections P and Q, is at the rate of 1.9 watts per metre.

Section P: Likewise with brackets, but with intensive reflectors, provided with shading rings to prevent glare-effects, although the height of light-source was 7 metres. The illumination is better than in "O," but the diversity factor is greater while, due to the lamps being screened, visibility is better.

Section Q: Also on brackets and similar to Section "O," but in this instance the lamps are surrounded by opal glass, and consequently the light distribution is improved, and the power of the lamps could, if required, be increased without glare disturbance.

Section R: Holophane extensive-pattern fittings with 200-watt lamps on brackets are used here, but at double the spacings adopted in Sections "O" to "Q," the height being 7 metres and the consumption 3 watts per metre of road-centre run. The road is very curved, and therefore the fittings are placed on the inner side of the curve provided with lamps with reflectors in order to increase the light emitted towards the outer, and therefore, expanded margin of the curve. This arrangement, in addition to improving the quality of the illumination, has the advantage of permitting the abandonment of the central-suspension system.

J. E.

E.L.M.A. Illumination Design Course

Amongst recent lectures in the above course may be noted that by Mr. H. Lingard, on November 14th, when he dealt with floodlighting. Numerous types of apparatus were illustrated and described, and the lecturer pointed out how the applications of floodlighting are continually extending. To the general regret, Mr. R. W. Maitland was unable, owing to indisposition, to deliver his lecture on architectural lighting on November 21st. His place was taken by Mr. R. A. Duncan, who proved to be an efficient substitute. Mr. Duncan gave an interesting address reviewing changes in architectural style as illustrated in buildings ranging from the ancient Acropolis at Athens to the highly modern Titania Palast in Berlin. He pointed out the dominating influence of the use of steel and the application of electricity, and showed, by the aid of lantern slides, how modern lighting demanded the joint efforts of the architect and the technical expert. In particular he emphasized the importance of avoiding monotony in lighting, referring to the the impressive vertical shadows utilized in some of Gordon G. Craig's stage sets.

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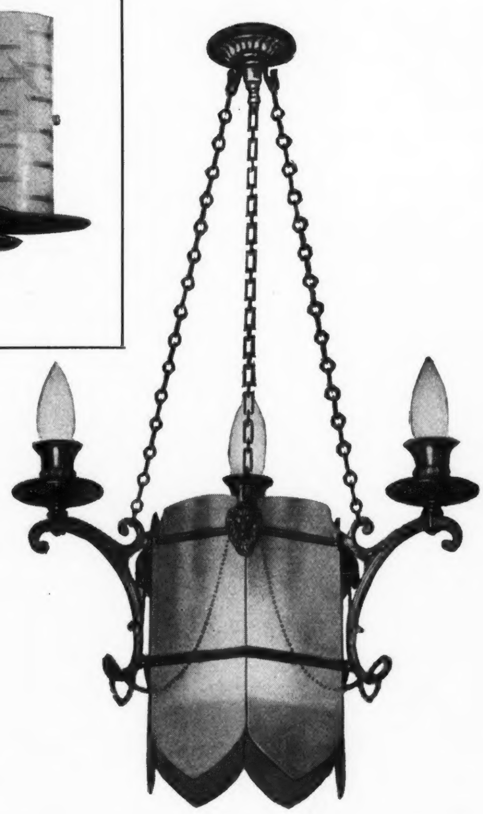
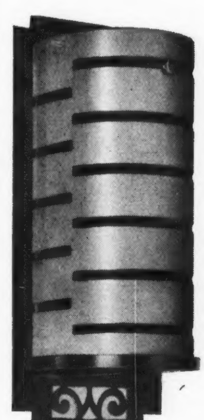
F. 9711
Chromium Plated Pendant with etched glassware in either white, pink or amber.



F. 9901
Gilt colour Pendant with glass panels tinted amber or flame colour.



F. 9714
Bracket Fitting in either Chromium plate or Grecian Bronze with etched glassware in various colours.

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Electric Lighting of Buildings

THE joint paper read before the Institution of Electrical Engineers by Mr. A. B. Read and Dr. J. W. T. Walsh, on November 3rd, was divided into two sections. The first part discussed the relationship between lighting design and practice in modern architecture and decoration; the second part was devoted to engineering and physiological aspects of lighting.

At the commencement of the paper attention was drawn to the profound change in the character of architecture in the period following the war. The full explanation of this change is debatable, but undoubtedly the new materials available to the architect have led to new forms of design. Electric lighting, it is suggested, should be adapted to this new environment. The product of design should be pleasing to the eye as well as practical in use; sources of light may now form an integral portion of the building. Electric lighting, however, is regarded not only a necessary and decorative feature, but is becoming the *raison d'être* of new architectural form. Many big public buildings (cinemas, theatres, concert halls and restaurants) either purposely exclude daylight or are only used at night. In such cases lighting becomes to a great extent responsible for the interior and exterior form of the building. Especially on the Continent, where courageous experiments have been made, is this the case.

Dealing with the lighting of the home, the authors emphasized the varied appliances for "built-in" lighting now available. There is an odd tendency to concentrate on the perfecting of industrial processes and pay little attention to their ultimate use. An intricate system of installation, cables, switches and lamps is often applied to operate lighting crudely conceived. It is, however, not in the homes of the rich or the highly intellectual that the best decoration or lighting is found, but rather in houses or flats occupied by intelligent people whose general outlook is unprejudiced and progressive. "They furnish . . . for the reason that they enjoy their surroundings. They judge period or modern work by the same standards, and their desire to possess is influenced only by the standard of design."

Instances of the use of lighting to produce a different atmosphere or to accentuate architectural features were given, and the application of the new methods to living rooms, bathrooms, kitchens, etc., were discussed.

In the concluding part of the first section of the paper the application of the latest methods of lighting to public buildings was reviewed. Such installations as those in the Titania Palast and the Kino Universum in Berlin were mentioned, and the famous illuminated canopy over the Galeries Lafayette in Paris, since applied on a smaller scale to London buildings, was described. A special opportunity for constructive design is afforded by the modern liner, where a departure from time-honoured Jacobean or 18th century designs has recently been noticeable. Thus the lighting of the "Ile de France," "Bremen" and "Europa" has been treated in such a manner as to preserve the graceful ship-like characteristics that are apparent externally.

In Part II attention was drawn to the important results of the increased efficiency of electric lamps, coupled with higher intrinsic brightness. Whilst the use of a diffusing bulb diminishes this brightness very substantially it is recalled that the average brightness of the bulb is about 13 candles per square inch (and in the central portion of an internally frosted bulb is considerably brighter than the peripheral portions). As the limit of brightness specified in British Standard Specification No. 324 for a diffusing-glassware fitting is 3 candles per square inch, no portion of a diffusing lamp-bulb should normally be permitted to come within the field of view. On the other hand, for use in diffusing panels and many decorative fittings the opal or internally frosted bulb has the merit of diminishing "spottiness." Tubular filament lamps are now finding many applications in modern lighting, and the gaseous discharge lamps, with the latest development, the hot-cathode lamp, provide a wonderful range of colours. Combinations of such tubes may also be used to furnish an approximately "white" light.

Turning next to diffusing materials, the authors drew attention to the important parts played by transmission and reflection in the case of enclosed spaces bounded by diffusing glass. The performance of an opal glass may depend upon (*a*) the size of the particles and their nature, (*b*) the number of particles per unit volume, and (*c*) the absorption of the glass matrix. The latter is far more important in opal than in ordinary glass. "Perfect diffusion" is, however, by no means a necessity for lighting fittings. Frosted glass, acid-etched or sand-blasted, is useful for purposes of diffusion, and the light lost in transmission through such material is usually negligible. Diffusion may also be effected by reflection of light from some matt opaque surface, such as a white ceiling; but it is difficult to furnish a higher reflecting value than 80 per cent., and 60 per cent. is usually the best that can be maintained for any length of time.

In the next section the distinction between "discomfort glare" and "disability glare" is pointed out. In the experiments on street lighting at Leicester the opinion was formed that observers pay more attention to the former than the latter. The method of judging effects of glare based on "equivalent background brightness" is explained, and it is pointed out how the presence of a bright light in the field of view may diminish the sensitiveness of the eye and set a limit to the minimum change in brightness perceptible. Thus it is shown how a 100-watt lamp placed 8 ft. from an observer and located an angular distance of 9° from the line of fixation may result in the efficiency of the lighting system being reduced by 25 to 30 per cent. In the concluding portion of the paper the authors dealt briefly with contrast, shadows and colour, pointing out some of the difficulties in definition involved.

Recent Developments in Electric Lighting

A paper on the above subject was read before the Royal Society of Arts, on November 30th, by Mr. W. J. Jones. In the early part of the paper the author compared the "candle-hours" available for one penny from electric lamps, oil lamps, candles and matches, and gave an amusing illustration of the difficulties of furnishing modern lighting requirements in the Houses of Parliament by candles. The latter part of the paper dealt with new developments, and especially electric lighting in relation to architecture. Perhaps, however, the most interesting portion of the paper was the intermediate section, in which some tests of the relation between visibility and illumination were described. Of special interest was the record of the effects of vibration in slowing down the speed of reading in tubes, trams and buses. It is noteworthy that high illuminations, of the order of 20 foot-candles, seem to make the disabilities due to vibration less evident.

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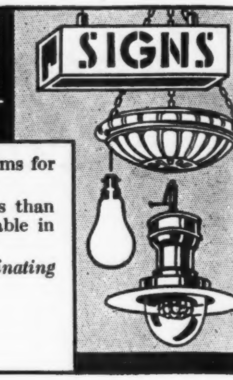

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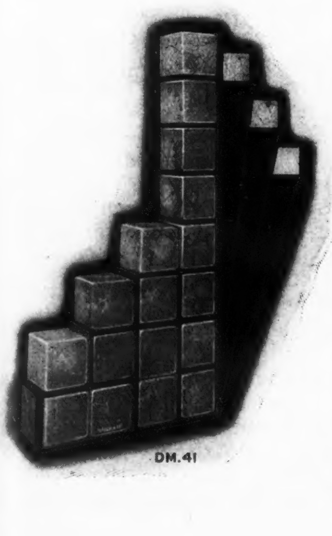
Show Window Lighting at Selfridge's



DM.41

Messrs. Hailwood & Ackroyd Ltd. have recently been responsible for the lighting of three large windows of Messrs. Selfridge's Ltd., in which effective use has been made of the luminous cubes of the type here illustrated, made in this country of Flakestone Alabaster glass. An illuminated glass archway has been built up. Varieties of this mode of lighting may be seen at the showrooms of Messrs. Hailwood & Ackroyd in New Oxford Street, London.

Sheffield Illumination Society

(*Communicated.*)

On November 7th last, Professor W. E. S. Turner, D.Sc., M.Sc., Sheffield University, gave a lecture to the members of the Sheffield Illumination Society on "Glass in the Service of Illumination," in the Y.M.C.A. Rooms, Fargate, Sheffield.

Professor Turner said that glass was originally manufactured in Venice, in the 13th and 14th centuries. Lighting was developed in the ægis of the Venetian glass-making industry, plain sheet glass being used in the old type of lantern.

Lantern slides were shown of the Woolworth Building, New York, and a new departmental store in Stuttgart, in which glass forms a very important part. It was found, however, that ordinary glass produced too much glare, therefore opal glass was evolved. In the Stuttgart store, alternate rows of opal and clear glass are so arranged to permit of a good window display at night.

Professor Turner showed various types of electric bulbs and coloured glasses used for advertising purposes, also pyrex heat-resisting glass. It was pointed out that glass can be prepared now in all shapes and all colours.

The lecturer went on to say that all glass is made alike, but it differs in properties and densities. The methods employed in bulb glass-making were explained in detail, it being pointed out that glass-making has developed into a science during the last 50 years. Several lantern slides giving information on these points were shown.

Professor Turner mentioned that two types of furnaces were used: (*a*) pot furnace and (*b*) tank furnace. Only the former type was used up to late in the 19th century. The pots are made of fireclay, and hold as little as $\frac{1}{4}$-cwt. up to two tons, with an average amount of glass of 15 to 25 cwts. The pots themselves may weigh from 15 to 25 cwts., and are about 3 ins. thick. The time required for melting varies according to the heat of the furnace and type of glass required. The mixture is melted to about 1,400° C., allowed to cool off until it becomes like treacle, when it can be gathered at the end of the glass-blower's pipe, and shaped as required. Professor Turner estimated the production of electric-light bulbs in this country to be between 70,000,000 and 80,000,000 a year. In the United States it was 400,000,000 a year. Lantern slides were shown of a factory in Holland. It was interesting to note the fine example of the organization and synchronization of labour in this factory. Ninety-six men worked around an eight-pot furnace, 15 or 16 ft. in diameter, and each produced about 100 bulbs per hour. The Westlake machine goes through the actions of hand-blowers, and produces between 70,000 and 90,000 lamps per day, i.e., one machine does the work of 100 glass-blowers.

Another interesting feature was the manufacture of glass-tubing and rodding. Molten glass flows on to a rotating mandril, and is drawn by machinery over pulleys at the rate of 100 to 250 ft. per minute. Under the old manual method of making tube 30 per cent. only of it was of any value, and this varied considerably both in thickness and diameter. The method of making pressed glassware and ply-glass was also discussed.

The general durability of glass in service was explained. The lecturer pointed out that it must be made so as to be water resistant—moisture apt to cause filming.

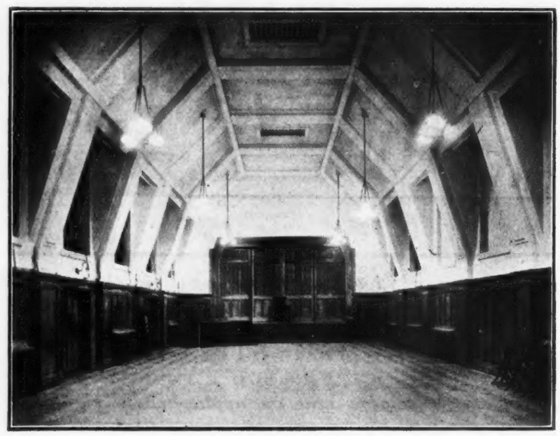
A good discussion followed the lecture. Replying to questions on opal glass and its absorption of light, Professor Turner said, in order to get the opacity it was necessary to have some element in suspension in the glass, which was itself opaque. It was therefore impossible to have an opal glass with a very low aborption, but he knew of opal glass being made in this country which had an absorption of only 15 per cent. Regarding miners' lamps, an amber dome has been tried in the lamp, and was thought to have alleviated nystagmus. It was explained that glass was made heat-resisting by having a low coefficient of expansion, and that high-power electric bulbs are able to stand heat without cracking because of their thinness.

Mr. J. F. Colquhoun, Public Lighting Engineer, Sheffield, occupied the chair, and at the conclusion of the meeting moved a vote of thanks to Professor Turner for his instructive address.

An Effective School Lighting Installation

An interesting recent school-lighting installation is that in the new Kingsbury Council School, which was recently opened by Dr. Cyril Norwood, the Head Master of Harrow. A new school of this character naturally affords a good opportunity for lighting, and we understand that the arrangements in this respect are quite up to date.

The accompanying illustration shows the fine Assembly Hall, 33 ft. by 80 ft. The view is taken looking towards the stage. The lighting is effected by eight 4-light reflector-refractor cluster fittings (a central Holophane No. 2,140), equipped with a 200-watt lamp, being surrounded by three No. 2,120 pieces, each equipped with 100-watt lamps. The fittings are mounted at a height of 18 ft., and are spaced approximately 20 ft. apart. Two similar (No. 2,130) units equipped with 200-watt lamps are suspended over the gallery.



The Assembly Room in the new Kingsbury (Middlesex) Council School.

We understand that the school has been equipped throughout with Holophane units, in accordance with a specification drawn up by Mr. Bray, of the Middlesex County Council.

X-ray Reflectors

A catalogue of X-ray reflectors, recently issued by the Edison Swan Electric Co. Ltd., serves as a reminder that the moulded mirrored glassware used in these lighting units is now entirely British made, being in fact produced at the company's factory at Ponders End. The problem of applying the silvering in such a manner that it will adhere to the glass and withstand high temperatures has now been solved, and it is stated that the reflectors now put upon the market are better than the imported variety. The catalogue also draws attention to several distinctive features, such as the "silver dome," the "dimple," and the "anti-glare" shield.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